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INSTRUMENTATION, FIELD TESTING, AND FATIGUE EVALUATION OF SELECTED APPROACH SPANS OF THE THROGS NECK BRIDGE (TN-82) OVER THE EAST RIVER, NEW YORK

Final Report

by

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Ian C. Hodgson
Carl A. Bowman

Prepared for
Parsons
TBTA

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APPENDIX D – Weigh-In-Motion Study

EXECUTIVE SUMMARY

The Throgs Neck Bridge was built in 1961 connecting the boroughs of Queens and the Bronx in New York City. The bridge consists of simple approach spans leading to the main suspension span of the bridge. Cracking problems have been identified at various details on the bridge. To alleviate the cracking problem, Parsons Transportation Group (PTG) developed different retrofit schemes and installed them in different spans to investigate the performance of each scheme and its effect on minimizing the potential for crack development. In addition, a detailed 3D finite element model was developed by PTG for further studies of the retrofit schemes. To calibrate the finite element model, evaluate both short and long-term performance of the prototype details, and to assess the global behavior of the bridge as a system, field measurements were performed by ATLSS researchers at selected portions of five approach spans on the bridge (Span 34, Span 35, Span 36, Span 38, and Span 45). Field measurements consisted of controlled load tests, where trucks with known weights were driven across the spans, and long-term monitoring where the instrumented locations were monitored under random live load traffic for approximately just over one month. The instrumentation consisted of installing weldable and bondable resistance strain gages, displacement sensors, accelerometers, and thermocouples for temperature measurements.

With the exception of the cutout shear connector details, the controlled load tests and the long-term monitoring indicated low stresses at the instrumented locations. Although slightly high, the stresses at the cutout details of the shear connectors were below the Constant Amplitude Fatigue Limit (CAFL) of a Category A detail. A fatigue evaluation using stress-range histograms developed during the long-term monitoring indicated high (over 100 years) or infinite remaining fatigue life for all of the instrumented fatigue-prone details. Laboratory fatigue data are not available for some of the instrumented details and therefore, no fatigue evaluation was conducted for these details.

In addition to the field testing program described above, Weigh-In-Motion (WIM) data were collected from the bridge and used by PTG in conducting a site-specific fatigue evaluation of the bridge. The data was also used to correlate certain events in the time-history response of a particular strain gage (strain gage data), with the axle weight producing such stress (WIM data) and the type of vehicle causing the stress, including multiple presence of vehicles (video data). Video data were collected through the installation of two cameras near the anchorage span of the bridge. A discussion on the WIM study can be found in Appendix D.

1.0 Project Summary and Background

1.1 Introduction

The Throgs Neck Bridge in New York City was opened to traffic in January of 1961 as a reaction to the steadily increasing traffic jams on the Triboro and Bronx-Whitestone Bridges. The bridge carries Interstate 295 and connects the boroughs of Queens and the Bronx. The bridge system consists of an 1800 ft main suspension span with simple straight and curved approach spans. The superstructure of the approach spans includes lateral bracing system, the main girders, floorbeams, sub-floorbeams, stringers, and orthotropic deck, which was installed in the 1980's to replace the existing deteriorated concrete deck. The total length of the bridge is 13,400 ft. An aerial photograph of a portion of the bridge complex is contained in Figure 1.1.

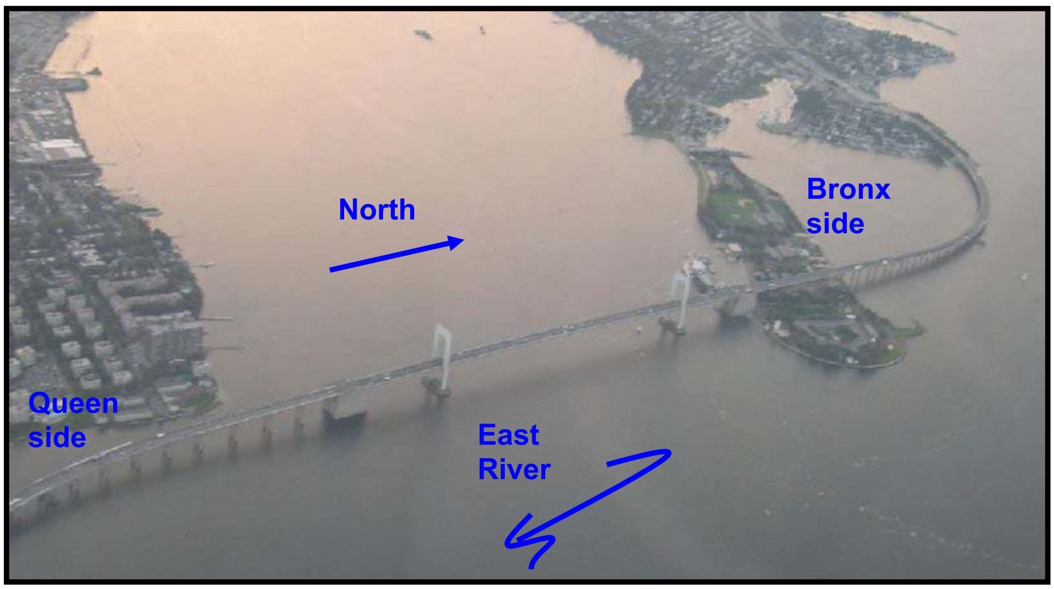


Figure 1.1 – Aerial photograph of a portion of the Throgs Neck Bridge
(Courtesy of http://en.wikipedia.org)

An in-depth field inspection of the bridge's orthotropic deck and the supporting structures of the approach spans, performed by others, revealed cracking problems at various details. Fatigue cracks caused by out-of-plane bending of lateral gusset plate riveted connections were found in the floorbeam webs. Furthermore, bolt failures were found at the through rib strap plate connection to sub-floorbeam top flange. Additionally, fatigue cracks were found in the sub-floorbeam webs, which appear to have originated at the blocked flange of the sub-floorbeams and propagated into the sub-floorbeam web. Parsons Transportation Group (PTG) developed different retrofit schemes and investigated the performance of each scheme through a detailed 3D finite element analysis. However, due to the complexity of the structural system and due to the various unknowns such as the load path and the degree of fixity at the stringer-to-floorbeam connections, it was decided to validate the analysis by performing field measurements on the spans containing the retrofit schemes (Span 34, 35, 36, and 45). In addition to the field measurements on the selected retrofitted spans, field measurements were also conducted on a control span (Span 38) representing one of the as-built straight approach spans such that a baseline could be established and comparison could be made between the performance of the spans before and after retrofit.

As described above, the spans where the retrofit schemes were installed and field measurements were conducted are Spans 34, 35, 36, and 45. Spans 34, 35, and 36 are 191 ft long straight line two-girder simple-spans and consist of the orthotropic deck, two main girders, floorbeams, sub-floorbeams, and lateral bracing system. Span 45 is a curved girder simple-span with horizontal length of approximately 165 ft and superstructure similar to the other three spans. Below is a list of the retrofit schemes implemented on the spans *(CAD drawings showing the retrofit schemes for each span can be found in Appendix A.)*

Span 34

- Welded/bolted shear connectors between the main girders and the orthotropic deck plate at each end of the span

Span 35

- Different repair types for the web of end floorbeams and various intermediate floorbeams at the floorbeam/girder intersection

Span 36

- Bolted shear connectors between the main girders and the orthotropic deck plate at each end of the span
- Different repair types for web of end floorbeams and various intermediate floorbeams at the floorbeam/girder intersection
- New sub-floorbeam8 and new end sub-floorbeam 9
- Keeper blocks on both sides of the orthotropic rib plates

Span 38 (Control Span

- No retrofits

Span 45

- Bolted shear connectors between the main girders and the orthotropic deck plate at each end of the span
- Different repair types for web of end floorbeams and various intermediate floorbeams at the floorbeam/girder intersection
- New sub-floorbeam8 and new end sub-floorbeam 9
- Keeper blocks on both sides of the orthotropic rib plates

To investigate the effectiveness of the retrofit schemes and the in-situ overall behavior of the retrofitted and the as-built approach spans, Lehigh University's ATLSS Center was contracted by the firm of Parsons Transportation Group to perform field testing on the four retrofitted spans (Span 34, 35, 36, and 45) as well as the as-built baseline span (Span 38). This testing consisted of a series of controlled-load tests with trucks of known weight as well as long-term monitoring over a period of over one month. In addition, a Weigh-In-Motion (WIM) study was carried out concurrently to assess the effect of truck weight and the multiple presence of trucks on the fatigue performance of the retrofitted and non-retrofitted details and to evaluate the truck traffic on the bridge (i.e., vehicle type, configuration, weight, and speed). The spans were instrumented with strain gages, displacement sensors, accelerometers, and thermocouples. The instrumentation was installed only on the east side of the bridge (northbound).

1.2 Instrumentation and Data Acquisition

The following section describes the instrumentation used for the controlled load testing and long-term monitoring. The instrumentation was installed on Span 34, 35, 36, 38, and 45. Detailed instrumentation plans for each span can be found in Appendix A.

1.2.1 Strain Gages

Strain gages were installed to capture both the local response of particular details and the global response of the instrumented spans. Both weldable and bondable uniaxial strain gages were used. Both types of gages were produced by Measurements Group Inc and are temperature-compensated for use on structural steel. The gages resistance is 350Ω and an excitation voltage of ten volts was used.

For ease of installation, weldable gages were used in most locations since they are much easier to install in the field than bondable gages. The weldable gages were type LWK-06-W250B-350 with an active grid length of 0.25 inches. The weldable gages were pre-bonded to a metal strip by the manufacturer and spot welded to the tested structure in the field. Grinding and cleaning was the only preparation needed for the metal surfaces before the installation of the gages. The gage itself is pre-bonded to a metal foil by the manufacturer. It is then spot welded to the structure in the field. After installation, gages were covered with multi-layer system then sealed with a silicon type agent.

Both biaxial and triaxial bondable strain gages were also used. The biaxial gages were type CEA-06-250WQ-350 manufactured by Measurements Group, Inc., with an active grid length of 0.125 inches. The triaxial gages were type CEA-06-250UR-350 manufactured by Measurements Group, Inc., with an active grid length of 0.125 inches. These gages were attached to the steel using a special adhesive at the desired location. Grinding and cleaning is also required, but the steel surface must also be prepared with special chemicals. The quality of the surface is much more critical for the successful application of a bondable strain gage. After installation, the gages were prepared with the same weatherproofing system used for the weldable gages.

1.2.2 Displacement Sensors

Linear motion position sensors manufactured by Duncan Electronics Division, BEI Technologies, Inc. were used and mounted on the bridge at various locations. The sensors have a displacement range of ±1/2 inch and theoretically have infinite resolution. The resolution of the measurement, however, is limited by the data acquisition system and was approximately 1×10^{-5} in. The sensors are encased in a plastic housing and are suitable for use in harsh environments.

1.2.3 Accelerometers

Uniaxial accelerometers were used in this study. The accelerometers were manufactured by PCB Piezotronics, Inc. The model used was 3701G3FA3G. The performance parameters of interest are summarized in Table 1.1. This model is termed capacitive (or DC) accelerometers. The primary component of these sensors is an internal capacitor. When subjected to acceleration, the sensor outputs a voltage in direct proportion to the magnitude of the acceleration. They are specifically designed for measuring low-amplitude, low-frequency accelerations.

Accelerometer Parameters	
Model	3701G3FA3g
Sensitivity	1000 mV/g
Measurement Range	±3g peak
Frequency Range	0 to 100 Hz
Broadband Resolution	30 μg rms
Number Used	5

Table 1.1 - Performance parameters of accelerometers used

1.2.4 Thermocouples

Thermocouple wire manufactured by Omega Engineering, Inc. was used to record surface temperatures of the bridge on the underside of the deck plate and the top flange of the girder at the north and south ends of each monitored span. The thermocouple was T-Type, (copper-constantan) with maximum temperature of 200 °C. The data acquisition system contains an on-board platinum resistance thermometer (PRT) to provide a reference temperature for thermocouple measurements. A heavy copper grounding bar and connectors is combined with the case design to reduce temperature gradients for accurate measurements.

1.2.5 Data Acquisition

Campbell Scientific CR9000 Data Loggers were used for the collection of the data throughout the controlled load testing and long-term monitoring. This logger is a high speed, multi-channel 16-bit system. The data loggers were configured with digital and analog filters to assure noise-free signals. Three loggers were used for data collection in all five spans. Specifically, the first data logger was used to monitor the channels installed on Span 34 and Span 35, the second data logger was used to monitor the channels installed on Span 36 and Span 38, and the third data logger was used to monitor the channels installed on Span 45. Each data acquisition system including the data logger and the displacement sensor and accelerometer power supply were enclosed in a weather-tight steel enclosure (total of three enclosures) as shown in Figure 1.2 and Figure 1.3. The first steel enclosure housing the data acquisition system used for data collection on Span 34 and Span 35 was mounted to the catwalk between both spans (i.e. at the north end of Span 34 and the south end of Span 35). The second steel enclosure housing the data acquisition system used for data collection on Span 36 and Span 38 was mounted to the catwalk at the north end of Span 36. The third steel enclosure used for data collection on Span 45 was placed on the temporary work platform beneath the span.

Figure 1.2 – Weather-tight enclosure mounted to the catwalk and used for housing the data acquisition system during the controlled load testing and long-term monitoring of Span 34 and Span 35 (similar enclosure was used for monitoring Span 36 and Span 38)

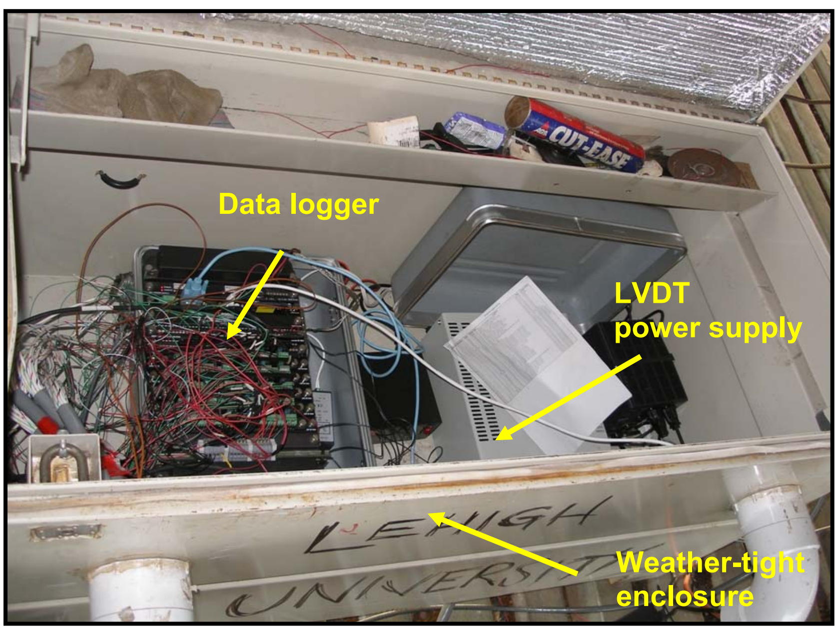


Figure 1.3 – Data acquisition system inside a weather-tight enclosure used for data collection during the controlled load testing and long-term monitoring of Span 45 located on the temporary work platform beneath the span

2.0 Remote Long-term Monitoring

CR9000 data loggers were also used for the long-term monitoring of the spans. Stress-time history data were not collected continuously. Data were only recorded when the measured stress at selected gages exceed predefined triggers. Once the strain value for that gage reached the limit defined, the logger started recording data for all the gages on the bridge for a predefined period of time. However, stress-range histograms were developed continuously for each location monitored.

In addition, a video camera was mounted on the guard rail of the suspension cables at the north end of the anchorage span in the southbound direction. The camera was set for continuous monitoring on the bridge and aimed towards the WIM sensors to assist in identifying the type of vehicles crossing over the bridge. A second camera was installed on the overhead sign gantry located near the north end of the anchorage span in the southbound direction (see Appendix C). The camera was positioned to capture images of vehicles crossing Span 34 and Span 35. The captured images assisted in identifying the configuration, position, and number of trucks producing a specific large stress cycle in Span 34 and Span 35. The camera was triggered by the logger when a moving vehicle caused the strain to reach a certain value in a particular gage. When the camera was triggered, a video was recorded for a predefined period of time. It is important to note that initially the camera was mounted on light pole 118 located on the southbound curb. However, excessive vibration of the light pole caused the camera to malfunction and a new camera was therefore installed on the sign gantry, as noted above, instead of a light pole.

Remote communication with the logger and camera was established using a wireless cellular modem. The remote communication allowed program upload and data download to be performed from the ATLSS Research Center in Bethlehem, PA.

3.0 Controlled Load Tests

A series of controlled load tests were conducted using six test trucks with known weight and geometry. Each truck had total of five axles (three truck axles and two trailer axles). The test was conducted with all five axles carrying the load of the truck (i.e., no axle in the up position). Each test truck was loaded with heavy steel blocks. The load of each axle was measured on-site using a portable scale, and the gross vehicle weight (GVW) of each truck was calculated. Table 3.1 contains a summary of the axle weights and GVW for each test truck. Table 3.2 provides the dimensions for each test truck.

Truck #	Front Axle Load (lb)	Sec. Axle Load (lb)	Third Axle Load (lb)	Fourth Axle Load (lb)	Rear axle Load (lb)	GVW[1] (lb)	Date of Tests
1	12,720	17,680	16,920	18,940	18,120	84,380	August. 15 & August 16, 2005
2	11,080	17,660	16,370	19,690	20,510	85,310	
3	10,690	15,700	15,120	22,400	16,370	80,280	
4	11,070	17,370	13,680	28,140	23,800	94,060	
5	11,660	16,050	14,990	18,110	19,800	80,610	
6	12,200	17,880	17,030	23,960	17,610	88,680	

Note:
1. GVW = Gross Vehicle Weight

Table 3.1 – Test trucks axle load data

Truck #	L1 (in)	L2 (in)	L3 (in)	L4 (in)	W_f (in)	W_r (in)	A[1] (in)	B (in)	C (in)	D[1] (in)	E (in)
1	208	53	379	49	80	74	-	10	21	-	7.5
2	173.5	54.5	376	49	81.5	79	-	8	22	-	9
3	176	52	373	48	79	78	-	7	22	-	9
4	179	52	367	49	80	73	-	7.5	21.5	-	8.5
5	185	53	273	50	80.5	73	-	10	22	-	10
6	179	54	299	49	80	74	-	8	22	-	8

Note:
1. This dimension was not measured.

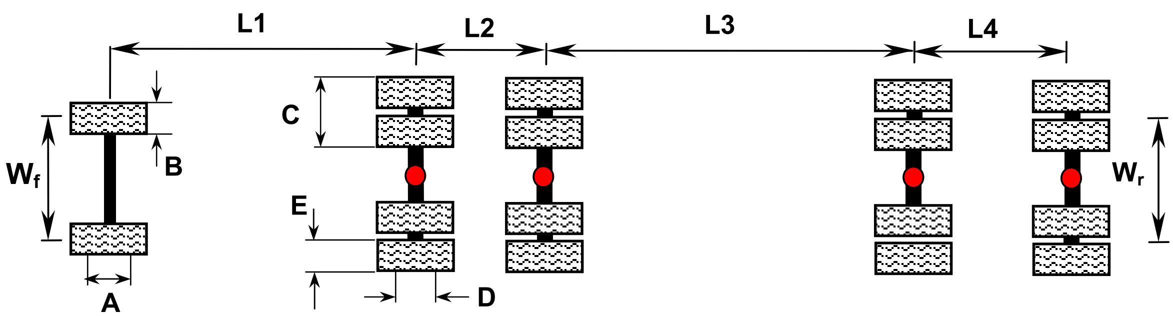


Table 3.2 – Geometry of the test trucks used in the controlled load tests

The controlled load tests were conducted between the hours of 11:00 PM and 4:00 AM on the nights of August 15 and August 16, 2005. The tests consisted of a series of crawl, dynamic, braking, and multiple presence tests and were performed while the south bound side of the bridge was opened to traffic (the north bound side was closed temporarily during each test). For the crawl tests, the test trucks were driven across all instrumented spans at speed of approximately 3-5 mph. All six trucks with various lane positions and configurations were utilized during the crawl tests (i.e., trucks crossing separately over single lanes or side-by-side over multiple lanes). The dynamic tests were conducted with the trucks traveling at speeds of approximately 25 and 50 miles per hour across the instrumented spans. Similar to the crawl tests, all six trucks with different transverse positions were utilized. The braking tests were conducted on all instrumented spans except Span 34 with the test trucks traveling at speed of approximately 50 mph immediately before breaking. Finally multiple presence tests were conducted on all spans with all six trucks traveling side-by-side in all six lanes (north bound and south bound) at a speed of 3-5 mph.

As discussed previously, data loggers were installed at three different locations during the controlled load tests. Each logger was manned by an ATLSS researcher during the tests. The first data logger was used for data collection of channels installed in Span 34 and Span 35 and was given the number "34". The second data logger was used for data collection of channels installed in Span 36 and Span 38 and was given the number “36”. The third data logger was used for data collection of channels installed in Span 45 and was given the number “45”. The use of one data logger for data collection on Span 34 and Span 35 resulted in one data file for each controlled load test on these two spans. Similarly, the use of one data logger for data collection on Span 36 and Span 38 resulted in one data file for each controlled load test on these two spans. Data files were named to reflect the nature of the test (i.e., crawl, dynamic, breaking, or multiple presence), the test number, and the logger used for data collection. For example the data file CRL1_34.DAT refers to the data file (.DAT) containing measurements of the first crawl test (CRL_1) conducted on Span 34 and Span 35 using logger number 34. Tables 3.3 through 3.5 below list the designation of the controlled load tests and a summary of each test.

3.1 Summary of Controlled Load Tests

A summary of the controlled load tests performed on the nights of August 15 and August 16, 2005 is listed in Tables 3.3, 3.4, and 3.5 below.

Test	Speed (mph)	Direction/ Location	Truck Number	Comments
CRL1_34.DAT	3 - 5	NB/ All lanes/Span 34 &35	1, 2, 3, 4, 5, & 6	Trucks were 1 1/2 - 3 minutes apart. Truck 1 followed by truck 2 in the outside lane, truck 3 followed by truck 4 in the middle lane, truck 5 followed by truck 6 in the inside lane.
CRL2_34.DAT	3 - 5	NB/outside & middle lane/Span 34 & 35	(1& 2) & (3& 4)	Truck 1 in the outside lane and truck 2 in the middle lane (side-by-side). Truck 3 in the outside lane and truck 4 in the middle lane (side-by-side). Truck 3 and truck 4 crossed over the spans approximately 2 minutes after truck 1 and 2.
CRL3_34.DAT	3 - 5	NB/middle & inside lane/Span 34 & 35	(5 & 6) & (1& 2)	Truck 5 in the middle lane and truck 6 in the inside lane (side-by-side). Truck 1 in the middle lane and truck 2 in the inside lane (side-by-side). Truck 1 and truck 2 crossed over the spans approximately 2 minutes after truck 5 and 6.
CRL4_34.DAT	3 - 5	NB/All lanes/Span 34 & 35	(3, 4, 5) & (6, 1, 2)	Truck 3 in the outside lane, truck 4 in the middle lane, and truck 5 in the inside lane (all three trucks side-by-side). Truck 6 in the outside lane, truck 1 in the middle lane, and truck 2 in the inside lane (all three trucks side-by-side). Truck 6, 1, and 2 crossed over the spans approximately 2 minutes after truck 3, 4, and 5.
DYN1_34.DAT	25	NB/All lanes/Span 34 & 35	1, 2, 3, 4, 5, 6	All six trucks were approximately 1 minute apart. Truck 1 followed by truck 2 in the outside lane. Truck 3 followed by truck 4 in the middle lane. Truck 5 followed by truck 6 in the inside lane.
DYN2_34.DAT	50	NB/All lanes/Span 34 & 35	1, 2, 3, 4, 5, 6	All six trucks were approximately 1 minute apart. Truck 1 followed by truck 2 in the outside lane. Truck 3 followed by truck 4 in the middle lane. Truck 5 followed by truck 6 in the inside lane.
B_34.DAT	~ 50 immediately before breaking	NB/outside lane/Span 35	5	Recording started when truck 1 passed over the anchorage. Trucks were approximately 1 minute apart. Truck 1 braked over Span 45 in the outside lane, followed by truck 2 over the same span and the same lane, followed by truck 3 over Span 38 in the outside lane, truck 4 over Span 36 in the outside lane, and finally truck 5 over Span 35 in the outside lane (no breaking test for Span 34). The fifth event in the data file represents braking of truck 5 over Span 35.
M_34.DAT	3 - 5	NB & SB/All lanes (side-by-side)	(1, 2, & 3) in SB & (4, 5, & 6) in NB	All six trucks lined up across all lanes at mid span of Span 38. Truck 1, 2, and 3 side-by-side in the SB direction in the outer lane, middle lane, and inside lane, respectively. Truck 6, 4, and 5 side-by-side in the NB direction in the middle of Span 38 in the outer lane, middle lane, and inside lane, respectively. Truck 1, 2, and 3 moving forward SB, and truck 6, 4, and 5 moving back NB. The one event in the data file represents crossing of all six truck side-by-side.

Table 3.3 - Summary of the controlled load tests conducted on Span 34 and Span 35

Test	Speed (mph)	Direction/ Location	Truck Number	Comments
CRL0_36.DAT	N/A	SB/inside lane/Span 36 & 38	1, 2, 3, 4, 5, & 6	All six trucks headed south bound (1 minute apart) to get in position for the crawl tests on NB. Minimal traffic in the NB direction until after truck 4 crossed Span 36.
CRL1_36.DAT	3 - 5	NB/All lanes/Span 36 & 38	1, 2, 3, 4, 5, & 6	Trucks were 1 1/2 - 3 minutes apart. Truck 1 followed by truck 2 in the outside lane, truck 3 followed by truck 4 in the middle lane, truck 5 followed by truck 6 in the inside lane.
CRL2_36.DAT	3 - 5	NB/outside & middle lane/Span 36 & 38	(1 & 2) & (3 & 4)	Truck 1 in the outside lane and truck 2 in the middle lane (side-by-side). Truck 3 in the outside lane and truck 4 in the middle lane (side-by-side). Truck 3 and truck 4 crossed over the spans approximately 2 minutes after truck 1 and 2.
CRL3_36.DAT	3 – 5	NB/middle & inside lane/Span 36 & 38	(5 & 6) & (1 & 2)	Truck 5 in the middle lane and truck 6 in the inside lane (side-by-side). Truck 1 in the middle lane and truck 2 in the inside lane (side-by-side). Truck 1 and truck 2 crossed over the spans approximately 2 minutes after truck 5 and 6.
CRL4_36.DAT	3 – 5	NB/All lanes/Span 36 & 38	(3, 4, & 5) & (6, 1, & 2)	Truck 3 in the outside lane, truck 4 in the middle lane, and truck 5 in the inside lane (all three trucks side-by-side). Truck 6 in the outside lane, truck 1 in the middle lane, and truck 2 in the inside lane (all three trucks side-by-side). Truck 6, 1, and 2 crossed over the spans approximately 2 minutes after truck 3, 4, and 5.
DYN1_36.DAT	25	NB/All lanes/Span 36 & 38	1, 2, 3, 4, 5, 6	All six trucks were approximately 1 minute apart. Truck 1 followed by truck 2 in the outside lane. Truck 3 followed by truck 4 in the middle lane. Truck 5 followed by truck 6 in the inside lane.
DYN2_36.DAT	50	NB/All lanes/Span 36 & 38	1, 2, 3, 4, 5, 6	All six trucks were approximately 1 minute apart. Truck 1 followed by truck 2 in the outside lane. Truck 3 followed by truck 4 in the middle lane. Truck 5 followed by truck 6 in the inside lane.
B_36.DAT	~ 50 immediately before breaking	NB/outside lane/Span 38 & 36	3 & 4	Recording started when truck 1 passed over the anchorage. Trucks were approximately 1 minute apart. Truck 1 braked over Span 45 in the outside lane, followed by truck 2 over the same span and the same lane, followed by truck 3 over Span 38 in the outside lane, truck 4 over Span 36 in the outside lane, and finally truck 5 over Span 35 in the outside lane (no breaking test for Span 34). The fourth and third events in the data file represents braking of truck 4 and truck 3 over Span 36 and 38, respectively.
M_36.DAT	3 - 5	NB & SB/All lanes (side-by-side)	(1, 2, & 3) in SB and (4, 5, & 6) in NB	All six trucks lined up across all lanes at mid span of Span 38 prior to testing resulting in shift in the data on Span 38, which was accounted for in Chapter 5. Truck 1, 2, and 3 side-by-side in the SB direction in the outer lane, middle lane, and inside lane, respectively. Truck 6, 4, and 5 side-by-side in the outer lane, middle lane, and inside lane, respectively. Truck 1, 2, and 3 moving forward SB, and truck 6, 4, and 5 moving back NB. The one event in the data file represents crossing of all six truck side-by-side.

Table 3.4 - Summary of the controlled load tests conducted on Span 36 and Span 38

Test	Speed (mph)	Direction/ Location	Truck Number	Comments
CRL1_45.DAT	3 – 5	NB/ All lanes/Span 45	1, 2, 3, 4, 5, & 6	Trucks were 1 1/2 - 3 minutes apart. Truck 1 followed by truck 2 in the outside lane, truck 3 followed by truck 4 in the middle lane, truck 5 followed by truck 6 in the inside lane.
CRL2_45.DAT	3 – 5	NB/outside & middle lane/Span 45	(1& 2) & (3& 4)	Truck 1 in the outside lane and truck 2 in the middle lane (side-by-side). Truck 3 in the outside lane and truck 4 in the middle lane (side-by-side). Truck 3 and truck 4 crossed over the spans approximately 2 minutes after truck 1 and 2.
CRL3_45.DAT	3 – 5	NB/middle & inside lane/Span 45	(5 & 6) & (1& 2)	Truck 5 in the middle lane and truck 6 in the inside lane (side-by-side). Truck 1 in the middle lane and truck 2 in the inside lane (side-by-side). Truck 1 and truck 2 crossed over the spans approximately 2 minutes after truck 5 and 6.
CRL4_45.DAT	3 – 5	NB/All lanes/Span 45	(3, 4, 5) & (6, 1, 2)	Truck 3 in the outside lane, truck 4 in the middle lane, and truck 5 in the inside lane (all three trucks side-by-side). Truck 6 in the outside lane, truck 1 in the middle lane, and truck 2 in the inside lane (all three trucks side-by-side). Truck 6, 1, and 2 crossed over the spans approximately 2 minutes after truck 3, 4, and 5. **(data file was not retrieved)**
DYN1_45.DAT	25	NB/All lanes/Span 36 & 38	1, 2, 3, 4, 5, 6	All six trucks were approximately 1 minute apart. Truck 1 followed by truck 2 in the outside lane. Truck 3 followed by truck 4 in the middle lane. Truck 5 followed by truck 6 in the inside lane.
DYN2_45.DAT	50	NB/All lanes/Span 36 & 38	1, 2, 3, 4, 5, 6	All six trucks were approximately 1 minute apart. Truck 1 followed by truck 2 in the outside lane. Truck 3 followed by truck 4 in the middle lane. Truck 5 followed by truck 6 in the inside lane.
B_45.DAT	~ 50 immediately before breaking	NB/outside lane/Span 45	1 & 2	Recording started when truck 1 passed over the anchorage. Trucks were approximately 1 minute apart. Truck 1 braked over Span 45 in the outside lane, followed by truck 2 over the same span and the same lane, followed by truck 3 over Span 38 in the outside lane, truck 4 over Span 36 in the outside lane, and finally truck 5 over Span 35 in the outside lane (no breaking test for Span 34). Three events are shown in the data file. First two events are for trucks 1 & 2 braking over the span and the third event is for truck 3 as it crossed the span (no braking).
M_45.DAT	3 - 5	NB & SB/All lanes (side-by-side)	(1, 2, & 3) in SB and (4, 5, & 6) in NB	All six trucks lined up across all lanes on Span 46. Truck 1, 2, and 3 side-by-side in the SB direction in the outer lane, middle lane, and inside lane, respectively. Truck 6, 4, and 5 side-by-side in the NB direction in the outer lane, middle lane, and inside lane, respectively. Truck 1, 2, and 3 moving forward SB, and truck 6, 4, and 5 moving back NB. The one major event in the data file represents crossing of all six truck side-by-side. The first two minor events represent random NB traffic prior to positioning of test trucks on NB.

Table 3.5 - Summary of the controlled load tests conducted on Span 45

4.0 Summary of Instrumentation Layout

The following section summarizes the instrumentation plan used on the bridge. Detailed instrumentation plans are included in Appendix A.

4.1 Strain Gages on Superstructure Elements

Strain gages were installed on the superstructural elements of the five selected approach spans (Span 34, Span 35, Span 36, Span 38, and Span 45) and included gages on the main girders, floorbeams, sub-floorbeams, stringers, orthotropic rib, prototype shear connectors, and the underside of the steel deck. Some of the strain gages were installed at various fatigue-prone details to assess the remaining service life of the bridge. Other gages were installed at locations such that the overall behavior and global response of the bridge could be examined.

The instrumented fatigue-prone details included riveted members (such as main girder flange, floorbeam flange, and tie plate), WT's bolted to the web of retrofitted floorbeams, web plate of the prototype shear connector at cutout details, welded and bolted details of the shear connectors, deck plate at the termination of shear connectors, web of existing sub-floorbeams near blocked flange, top and bottom flange of the new sub-floorbeam near welded and bolted details, and the orthotropic rib plate.

It is important to note that laboratory fatigue test data are not available for some of the details listed above and therefore no fatigue category per ASSHTO Specifications could be assigned to these details. Measuring the stresses at these details however was important in understanding their response to moving load with known weight as well as random traffic.

4.1.1 Riveted Main East Girder Flange

Two strain gages were installed near midspan (4'-0" north of midspan) on the top and bottom flange, at mid width of the flange, of the east riveted girder in each of the five instrumented spans. With the exception of strain gage CH_60, the two gages at each span were installed at mid width of the flange, on the top face of the top flange and the bottom face of the bottom flange. Specifically, strain gages CH_4, CH_54, CH_33, CH_59, and CH_29 were installed on the top flange of the east girders in Span 34, Span 35, Span 36, Span 38, and Span 45, respectively, and strain gages CH_5, CH_55, CH_34, and CH_30 were installed on the bottom flange of the east girders in Span 34, Span 35, Span 36, and Span 45, respectively.

Because of the lack of access to the bottom face of the bottom flange of Span 38, strain gage CH_60 was installed on the top face of the bottom flange at approximately 1 inch from the edge of the flange. All gages were installed away from the rivets to measure the nominal stress in the flanges and avoid measuring any stress concentration caused by the rivet holes. Figure 4.1 shows strain gage CH_30 installed in Span 45, approximately 4 ft north of midspan, on the bottom face of the bottom flange of the east girder at mid width of the flange.

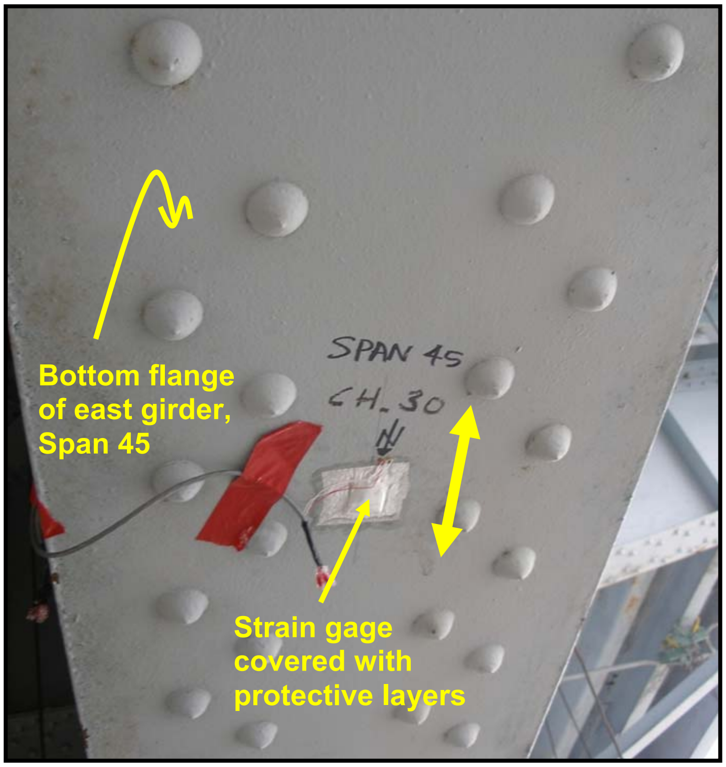


Figure 4.1 – Strain gage CH_30 installed at midspan of Span 45 and on the bottom face of the bottom flange of the east girder at mid width of the flange (view from the bottom up)

4.1.2 Riveted/Bolted Floorbeam Flange

Strain gages were installed on the top and bottom flange of Floorbeam 1 and Floorbeam 2 in Span 45. Strain gages FB1_Top and FB1_Bot were installed on the top and bottom flange, respectively, of Floorbeam 1 at 9 ft-1 in east of the centerline of the floorbeam (i.e., on the reduced section of the floorbeam flange at 1 in from the termination of the cover plate riveted/bolted to the bottom flange and 4 in from the edge of the flange). Strain gages FB2_Top and FB2_Bot were installed on the top and bottom flange, respectively, of Floorbeam 2, where gage FB2_Bot was installed at the centerline of the floorbeam on the bottom flange at 4 in from the edge of the flange and gage FB2_Top was installed at the centerline of the floorbeam on the bottom face of the top flange (because of accessibility) at 4 in from the edge of the flange. It is important to note that these gages were installed at a later date than the installation of all other gages and after the controlled load testing was conducted (i.e., no control load testing data exist for these gages).

Because controlled load test data on the floorbeam flange were not available, the response of the floorbeam (i.e., stresses in the floorbeam flanges) to known weight can only be determined analytically using the computer model developed by PTG. Data collected from all instrumented details on the spans (all details except the floorbeam flange) indicated that the response during the controlled load tests were less than the response during the long-term monitoring. Therefore, the same could be assumed for the riveted/bolted floorbeam flange.

The lack of controlled load test data did not affect the fatigue assessment of the riveted/bolted detail of the floorbeam flange since the long-term monitoring data is used for such assessment. The details were monitored for approximately 24 days, which is sufficient for conducting the fatigue assessment. Figure 4.2 shows strain gage FB1_Bot installed in Span 45 on the bottom face of the bottom flange of Floorbeam 1 at 9 ft-1 in east of the centerline of the floorbeam.

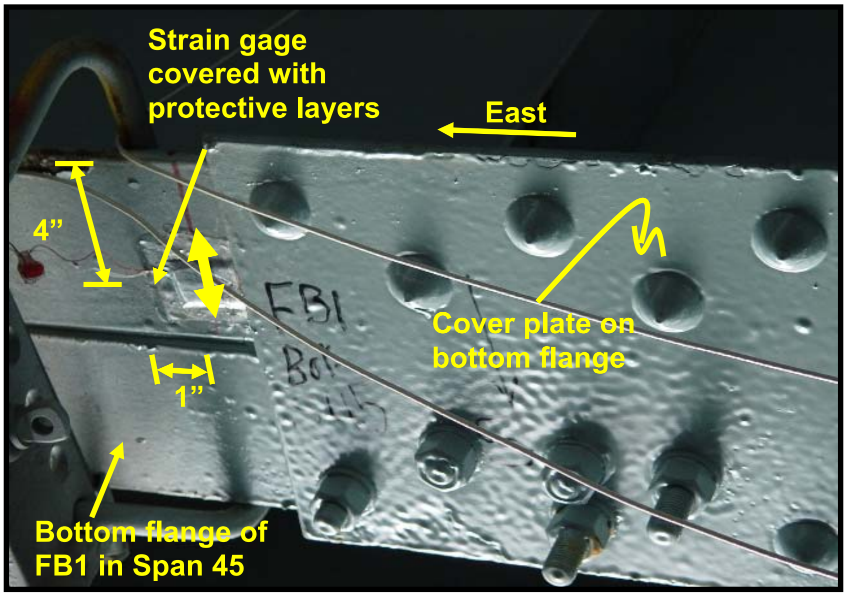


Figure 4.2 – Strain gage FB1_Bot installed in Span 45 on the bottom face of the bottom flange of Floorbeam 1 at 9 ft-1 in east of the centerline of the floorbeam (i.e., on the reduced section of the floorbeam flange at 1 in from the termination of the cover plate riveted/bolted to the bottom flange) and 4 in from the edge of the flange.
(view from the bottom up)

4.1.3 Riveted Tie Plate

Tie plates cross over the main east and west girders in the transverse direction and are used as continuity plates connecting the top flange of the floorbeam on one side of the main girder to the top flange of the floorbeam on the other side of the same girder. Strain gages were installed on the tie plates crossing transversely over the east girder.

Specifically, in Span 34, strain gage CH_12 was installed on the east tie plate of Floorbeam 8, at the south edge of the plate. In Span 35, strain gages CH_39 and CH_40 were installed on the east tie plate of Floorbeam 2, at the south and north edge of the plate, respectively.

In Span 36, strain gages CH_16 and CH_17 were installed on the east tie plate of Floorbeam 8, at the south and north edge of the plate, respectively. In Span 38, strain gages CH_45 and CH_46 were installed on the east tie plate of Floorbeam 2, at the south and north edge of the plate, respectively.

In Span 45, strain gages CH_12 and CH_13 were installed on the east tie plate of Floorbeam 2, at the south and north edge of the plate, respectively. With the exception of strain gages CH_16 and CH_17 installed in Span 36, the gages were installed on the east tie plate at approximately 4 in west of the centerline of the girder and 1 in from the edges of the tie plate. Strain gages CH_16 and CH_17 were installed on the tie plate at the centerline of the girder at 1 in from the edges of the tie plate. Figure 4.3 shows CH_12 and CH_13 installed in Span 45 on the east tie plate.

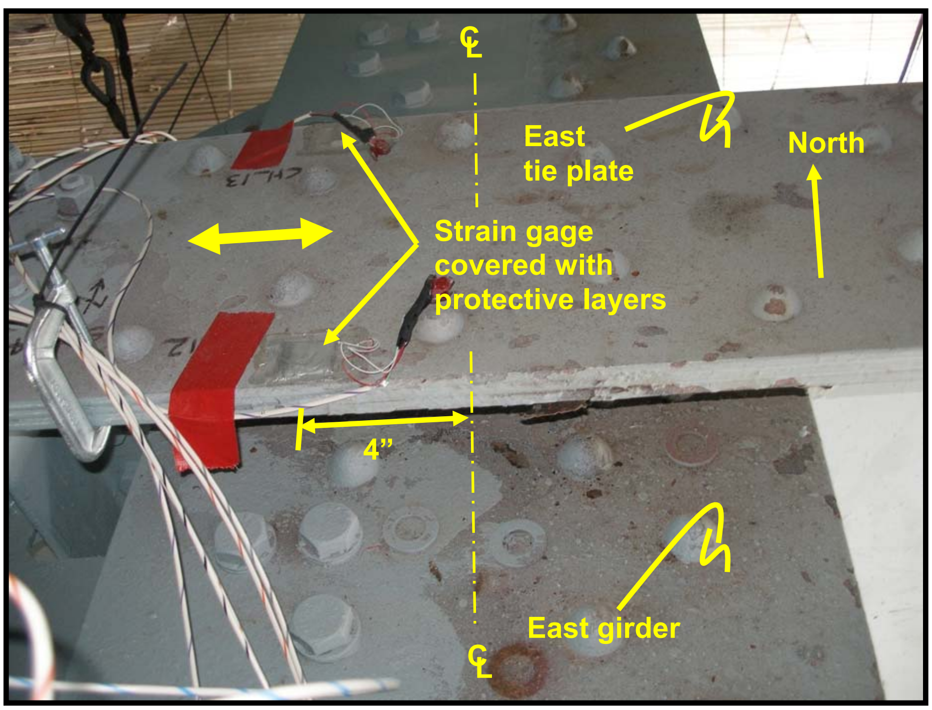


Figure 4.3 – Strain gage CH_12 and CH_13 installed in Span 45 on the east tie plate of Floorbeam 8, which crosses transversely over the east girder at approximately 4 in from the center line of the girder and 1 in from the edge of the tie plate.
(view looking north)

4.1.4 Web of Non-retrofitted Floorbeam of Span 38

In Span 38, the control span, strain gage CH_44 was installed on the web of Floorbeam 2 at a distance of approximately 21 1/2 in west of the centerline of the east girder and approximately 5 1/2 in below the bottom face of the floorbeam top flange. The gage was installed to serve as a baseline for comparison between the response of the non-retrofitted floorbeam web of Span 38 and the prototype floorbeam web retrofits installed in Span 35, 36, and 45.

4.1.5 WT-Section Bolted to Floorbeam Web

Different repair types for the web of end floorbeams and various intermediate floorbeams were installed in Span 35, 36, and 45. The retrofit included bolting a WT-section to the web of the floorbeam to increase the cross sectional area of the web at that location and reduce the out-of-plane stresses on the web induced by the lateral bracing system (the top lateral bracing system is bolted to the WT's through gusset plates). Strain gages were installed transversely on the WT's to measure the effectiveness of the retrofit in reducing the out-of-plane stresses. Specifically, strain gages CH_41, CH_18, and CH_15 were installed on the WT of Floorbeam 2 in Span 35 (south face of floorbeam web), the WT of Floorbeam 8 in Span 36 (north face of floorbeam web), and the WT of Floorbeam 2 in Span 45 (north face of floorbeam web), respectively.

The gages were installed on the WT's at a distance of approximately 21 1/2 in west of the centerline of the east girder and approximately 5 1/2 in below the bottom face of the floorbeam top flange. Figure 4.4 shows strain gage CH_41 installed on the web of Floorbeam 2 in Span 35.

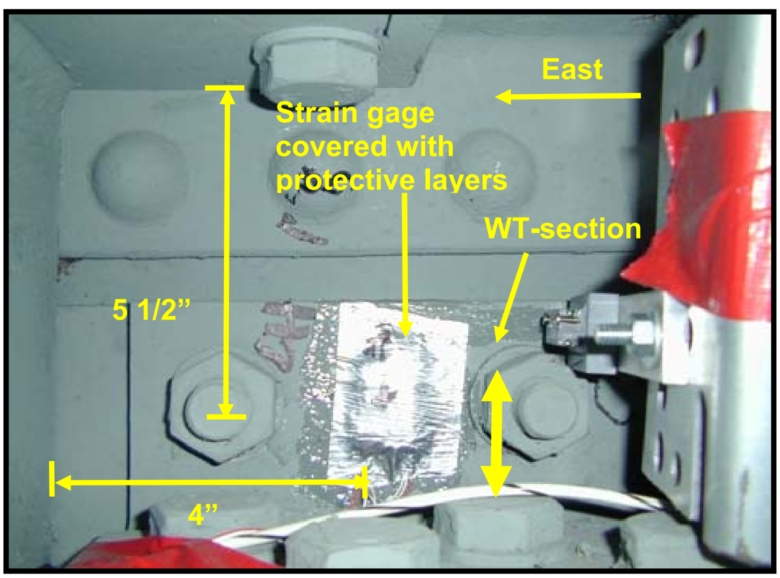


Figure 4.4 – Strain gage CH_41 installed in Span 35 on the web of Floorbeam 2 at the floorbeam/east girder intersection and at a distance of approximately 21 1/2" west of the centerline of the east girder and approximately 5 1/2" below the bottom face of the floorbeam top flange
(view looking south)

4.1.6 Web of Prototype Shear Connectors at Cutout Detail

Prototype longitudinal shear connectors were installed in Span 34, 36, and 45 at the north and south end of each span between the top flange of the main girders (east girder and west girder) and the underside of the steel deck plate. The intention of introducing the shear connectors is to minimize the longitudinal relative displacement between the orthotropic deck and the superstructure system. Strain gages were installed on the web plate of the east shear connector at fatigue prone details, which included the cutout details of the shear connector web plate, shear connector web plate along the longitudinal weld, and shear connector web plate near bolted angles.

In Span 34, strain gages CH_23 and CH_24 were installed back-to-back on the web plate at the south cutout detail of the shear connector located at the north end of the span. The gages were installed at a perpendicular distance of 1/4 in from the cut and at a vertical distance of approximately 27 in from the top face of the top flange of the east girder. Similarly, strain gages CH_25 and CH_26 were installed back-to-back on the same cutout at a perpendicular distance of 1/4 in from the cut and at a vertical distance of approximately 20 1/2 in from the top face of the top flange of the east girder.

In Span 45, strain gages CH_33 and CH_34 were installed back-to-back at similar location to the strain gages CH_23 and CH_24 installed on Span 34 (i.e., on the web plate of the shear connector at the south cutout detail of the connector located at the north end of the span at a perpendicular distance of 1/4 in from the cut and at a vertical distance of approximately 27 in from the top face of the top flange of the east girder). Strain gages CH_35 and CH_36 were installed on the same cutout at location similar to where strain gages CH_25 and CH_26 were installed in Span 34.

The gages were installed back-to-back to measure any localized out-of-plane bending stresses resulting from local or global bending of the plate, which could be caused by the vehicle load being transversely not centered over the shear connector web plate. The installation of the gages at a 1/4 in from the cutout assured capturing of the maximum stresses at the cutout. Figure 4.5 shows strain gage CH_33 and strain gage CH_35 installed on the web plate at the south cutout detail of the east shear connector located at the north end of Span 45.

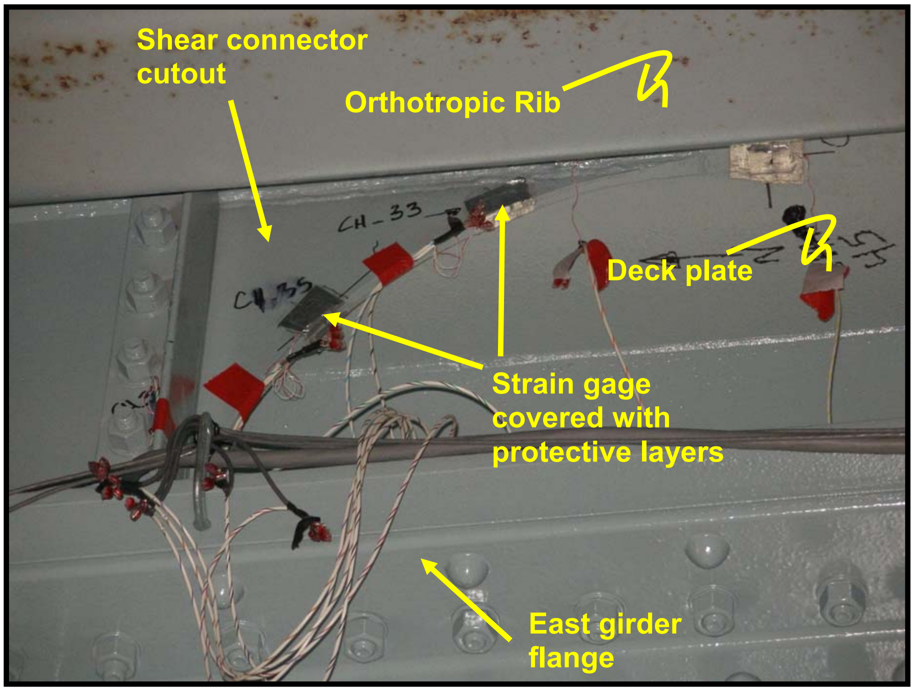


Figure 4.5 – Strain gage CH_33 and strain gage CH_35 installed at the cutout detail on the south end of the web plate of the north shear connector attached to the east girder in Span 45
(view looking east)

4.1.7 Web of Prototype Shear Connectors near Welded Detail

In Span 45, and in addition to the strain gages installed on the web plate of the north shear connector at the south cutout detail, strain gage CH_39 was installed on the web plate of the east shear connector near the north end of the span. The gage was installed along the longitudinal weld used for attaching the shear connector to the bottom face of the deck steel plate (Figure 4.6).

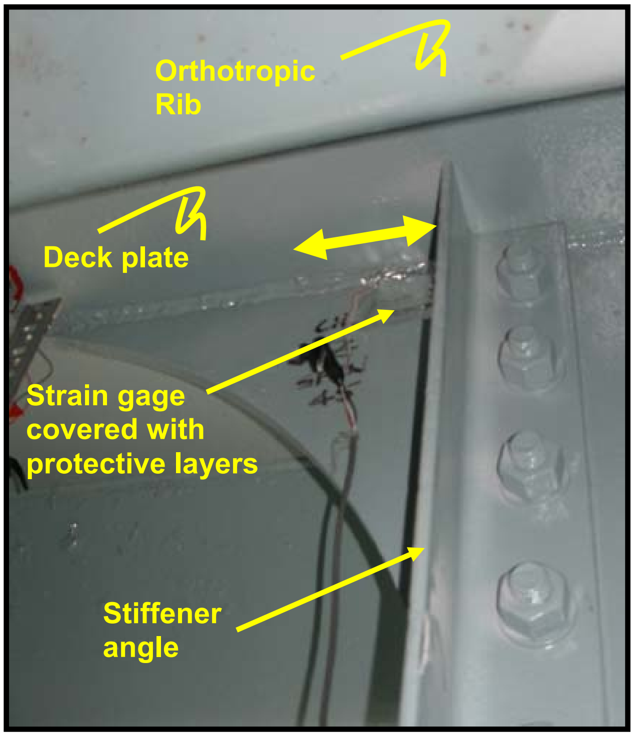


Figure 4.6 – Strain gage CH_39 installed on the web plate of the north shear connector near the north end of the connector and longitudinally along the longitudinal weld used for attaching the shear connector to the bottom face of the deck steel plate in Span 45 (view looking east)

4.1.8 Web of the Prototype Shear Connectors near Bolted Detail

In addition to the above mentioned gages, triaxial 45 degree strain gage rosettes were installed on the web plate of the shear connector near the north end of the plate and fit tight with the vertical angle element of the shear connector. The gages were installed back-to-back on both sides of the web plate to capture any distortional stresses that might exist in the plate. The gages were installed in Span 36 and Span 45.

In Span 36, gages CH_5, CH_6, and CH_7 were installed on the north shear connector (north end of the span) over the east girder and on the west face of the shear connector plate, where strain gage CH_5 was installed vertically on the web plate adjacent to the vertical stiffener angle, strain gage CH_6 was installed at 45 degree counter-clockwise from strain gage CH_5, and strain gage CH_7 was installed longitudinally along the longitudinal angle at 90 degree angle counter-clockwise from strain gage CH_5. Strain gages CH_8, CH_9, and CH_10 were installed directly behind strain gages CH_5, CH_6, and CH_7, respectively, on the east face of the shear connector web plate.

Similar strain gages were installed in Span 45, where gages CH_4, CH_5, and CH_6 were installed on the south shear connector (south end of the span) over the east girder and on the west face of the shear connector plate. Strain gage CH_4 was installed vertically on the web plate adjacent to the vertical stiffener angle, gage CH_5 was installed at 45 degree counter-clockwise from gage CH_4, and gage CH_6 was installed longitudinally along the longitudinal angle at 90 degree angle counter-clockwise from gage CH_5 as shown in Figure 4.7. Gages CH_7, CH_8, and CH_9 were installed directly behind gages CH_4, CH_5, and CH_6, respectively, on the east face of the shear connector web plate.

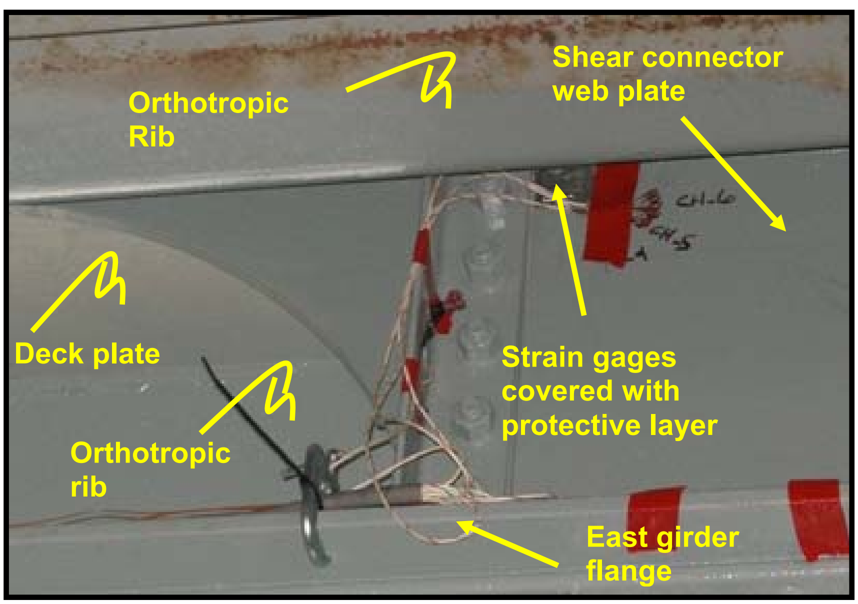


Figure 4.7 – Strain gages CH_4, CH_5, and CH_6 installed in Span 45 on the south shear connector (south end of the span) at the north end of the shear connector over the east girder and on the west face of the shear connector plate
(view looking east)

4.1.9 Standing Angle Bolted to Shear Connector

Strain gages were also installed on the vertical stiffener angle bolted to the web plate of the shear connector in Span 34, 36, and 45. In Span 34, strain gage CH_27 was installed on the north face of the outstanding leg of the south end stiffener angle bolted to the web of the shear connector at the north end of the span over the east girder (at mid height of the stiffener and mid width of the outstanding leg).

In Span 36, strain gages CH_3 and CH_4 were installed back-to-back on the south and north face, respectively, of the outstanding leg of the north end stiffener angle (at mid height of the stiffener and mid width of the outstanding leg) bolted to the web of the shear connector at the north end of the span over the east girder.

In Span 45, strain gages CH_10 and CH_11 were installed back-to-back on the south and north face, respectively, of the outstanding leg of the north end stiffener angle bolted to the web of the shear connector at the south end of the span over the east girder (at mid height of the stiffener and mid width of the outstanding leg). Strain gage CH_38 was installed in the same span on the north face of the outstanding leg of the south end stiffener angle bolted to the web of the shear connector at the north end of the span over the east girder (at mid height of the stiffener and mid width of the outstanding leg). Figure 4.8 shows strain gage CH_38 installed on the south end stiffener angle bolted to the web of the shear connector at the north end of the span over the east girder.

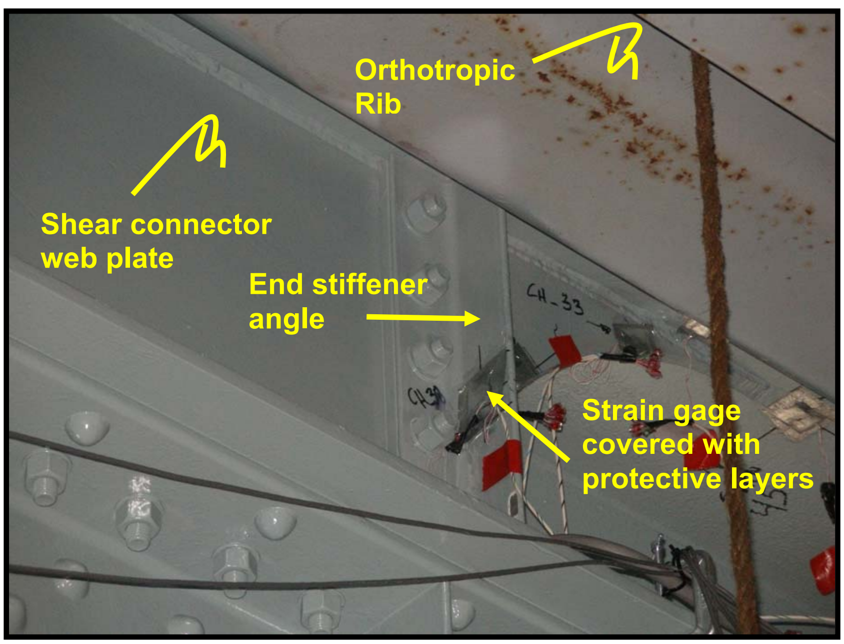


Figure 4.8 – Strain gage CH_38 installed in Span 45 on the south end stiffener angle bolted to the web of the shear connector at the north end of the span over the east girder (at mid height of the stiffener and mid width of the outstanding leg) (view looking east)

4.1.10 Underside of Deck Plate at the Termination of the Welded and Bolted Shear Connectors

Strain gages were installed on the underside of the deck plate at the termination of the bolted and welded shear connectors to measure the nominal stress range in the deck plate near the weld and the bolts used for attaching/connecting the prototype longitudinal shear connectors to the bottom face of the deck plate.

In Span 34, strain gage CH_28 was installed transversely on the bottom face of the deck plate at 2 in off-center from the shear connector web near the south end of the north shear connector installed in the span over the east girder (Figure 4.9). At the south end termination of the same shear connector, strain gage CH_29 was installed longitudinally on the bottom face of the deck plate at 1 1/2 in from the termination of the shear connector weld.

In Span 36, strain gage CH_2 was installed on the bottom face of the deck plate at the north end termination of the north shear connector located above the east girder. The strain gage was installed longitudinally on the bottom face of the deck plate at 1 1/2" from the termination of the shear connector bolted connection (shear connector bolted to the bottom face of the deck plate).

In Span 45, strain gage CH_32 was installed transversely on the bottom face of the deck plate at 2 in off-center from the shear connector web near the south end of the north shear connector installed in the span over the east girder. At the south end termination of the same shear connector, strain gage CH_37 was installed longitudinally on the bottom face of the deck plate at 1 1/2" from the termination of the shear connector weld.

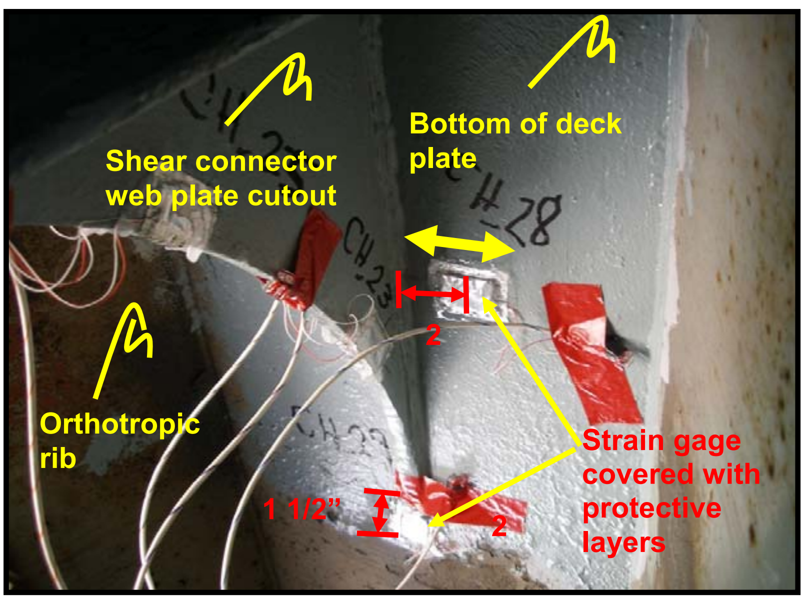


Figure 4.9 – Strain gage CH_28 installed transversely on the bottom face of the deck plate at 2 in off-center from the shear connector web near the south end of the north shear over the east girder and strain gage CH_29 installed longitudinally on the bottom face of the deck plate at 1 1/2 in from the termination of the shear connector weld
(view from the bottom up)

4.1.11 Web of Existing Sub-floorbeam near Blocked Flange at Sub-floorbeam-to-Stringer Connection

Cracking has been observed in the web of some of the existing sub-floorbeams near blocked flange at the sub-floorbeam-to-stringer connection. Biaxial strain gages were installed back-to-back on the web of selected existing sub-floorbeams to measure the magnitude of the stresses at the instrumented locations. The gages were installed back-to-back such that the out-of-plane stresses could be separated from the in-plane stresses. The spans where existing sub-floorbeams were instrumented are Span 34, 35, and 38.

In Span 34, biaxial strain gages were installed back-to-back on the web of existing Sub-floorbeam 8, 1 in below the blocked flange (between Rib 5 and Stringer 3). Specifically, strain gages CH_13 and CH_14 were installed horizontally and vertically, respectively, on the south face of the web of the sub-floorbeam and strain gages CH_15 and CH_16 were installed on the north face of the web directly behind gages CH_13 and CH_14, respectively.

In Span 35, biaxial strain gages were also installed back-to-back on the web of existing Sub-floorbeam 2 between Rib 5 and Stringer 3. The existence of a crack and an arrest hole on the web of the sub-floorbeam prompted the installation of the gages at 2 3/4 in below the blocked flange instead of 1 in as in Span 34. Strain gages CH_44 and CH_45 were installed horizontally and vertically, respectively, on the south face of the web of the sub-floorbeam. Strain gages CH_46 and CH_47 were installed on the north face of the web directly behind gages CH_44 and CH_45.

In Span 38 the gages were installed on the web of existing Sub-floorbeam 2 between Rib 5 and Stringer 3. The biaxial gages were installed back-to-back on the web at 2 3/4 in below the blocked flange. Strain gages CH_48 and CH_49 were installed horizontally and vertically, respectively, on the south face of the web of the Sub-floorbeam. Strain gages CH_50 and CH_51 were installed on the north face of the web directly behind gages CH_48 and CH_49.

The existence of the cracks on the web of the sub-floorbeams prevented the installation of the gages near the blocked flanges. This resulted in the peak stresses on the sub-floorbeam web not being captured. It is important to note that this type of crack exist in the web of sub-floorbeams in various approach spans and typically are located on the web of the two north end sub-floorbeams and the two south end sub-floorbeams. The sharp reentrant corner resulting from flame cutting the flange and the notch conditions resulting from the cutting process are high stress raisers that resulted in significant reduction in the fatigue strength of the detail, which otherwise would be classified as Category A detail per AASHTO Specifications. It is highly likely that cracking at the detail could have still occurred even if the notches were ground smooth. This is due to the existence of the sharp reentrant corner of the blocked flange.

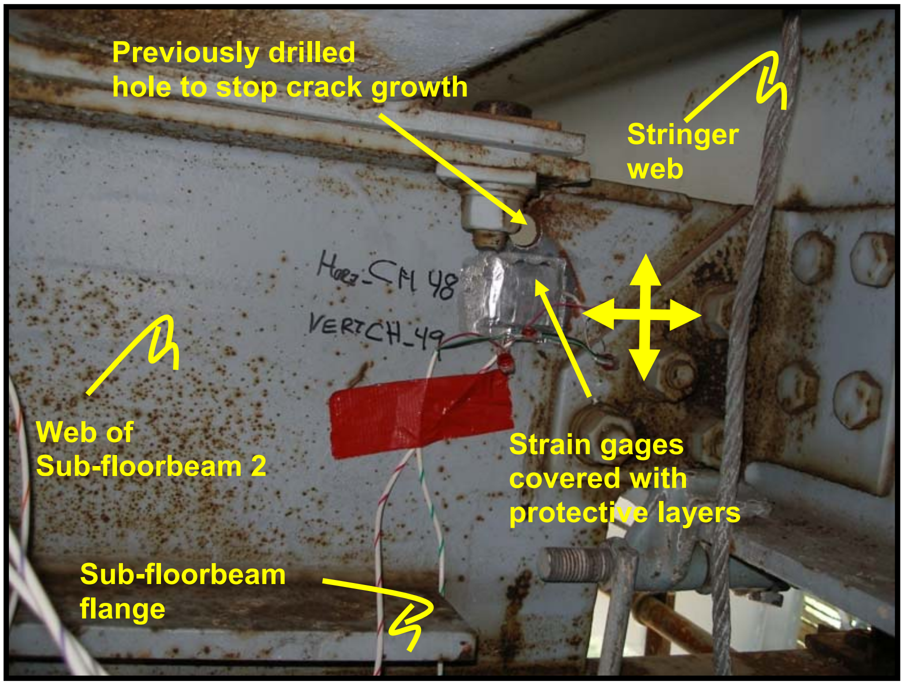


Figure 4.10 – Horizontal strain gage CH_48 and vertical strain gage CH_49 installed on the south face of the web of the Sub-floorbeam 2 in Span 38.
(view looking north)

4.1.12 Top and Bottom Flange of New Sub-floorbeam

Strain gages were installed on the top flange of the new prototype sub-floorbeams installed in Span 36 and Span 45 at the sub-floorbeam-to-stringer connection. The top flange of the new sub-floorbeams consists of the web of a built up T-section. The flange of the T-section is bolted to the web of the stringer to provide the connection between the sub-floorbeam and the stringer.

In Span 36, strain gage CH_20 was installed on the top flange (T-section web) of the new intermediate Sub-floorbeam 8 west of the web of Stringer 3 and near the south end of the flange edge at 1 in from the toe of the weld used for attaching the web and the flange of the T-section and at 1 in from the edge of the reduced section of the flange. Strain gage CH_21 was also installed similar to strain gage CH_20 near the north end of the flange at 1 in from the toe of the weld used for attaching the web and the flange of the T-section and at 1 in from the edge of the reduced section of the flange. On the east face of the stringer web, the strain gages were installed in a similar fashion to the previously installed gages on the west face of the stringer web such that CH_22 was installed near the south end of the flange, and strain gage CH_23 was installed near the north end of the flange. In addition to the strain gages installed on the top flange of the new sub-floorbeam in Span 36, two strain gages, CH_24 and CH_25, were installed on the bottom cover plate bolted to the bottom flange of the new Sub-floorbeam 8 as shown in Figure 4.12, where strain gage CH_24 was installed at 1 in from the south edge of the flange and strain gage CH_25 was installed at 1 in from the north edge of the flange.

In Span 45, strain gages were installed on the top flange of new Sub-floorbeam 2 similar to those in Span 36. Specifically, strain gages CH_21, CH_22, CH_19, and CH_20 in Span 45 were installed similar to strain gages CH_20, CH_21, CH_22, and CH_23, respectively.

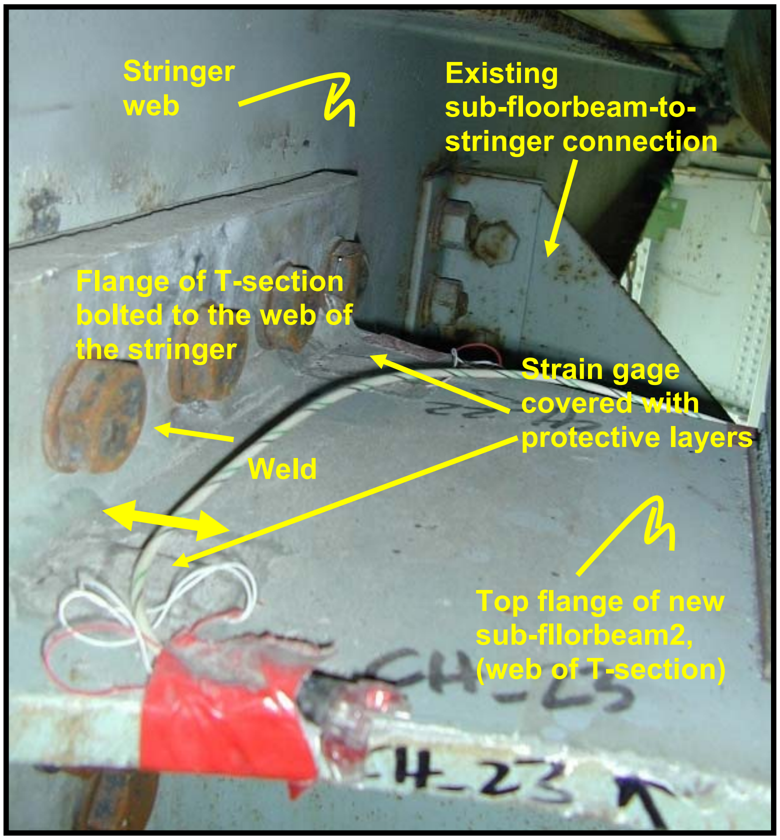


Figure 4.11 – Strain gages CH_22 and CH_23 installed on the top flange (T-section web) of the new intermediate Sub-floorbeam 8 west of the web of Stringer 3 and near the south end of the flange edge at 1 in from the toe of the weld used for attaching the web and the flange of the T-section and at 1 in from the edge of the reduced section of the flange (view looking north)

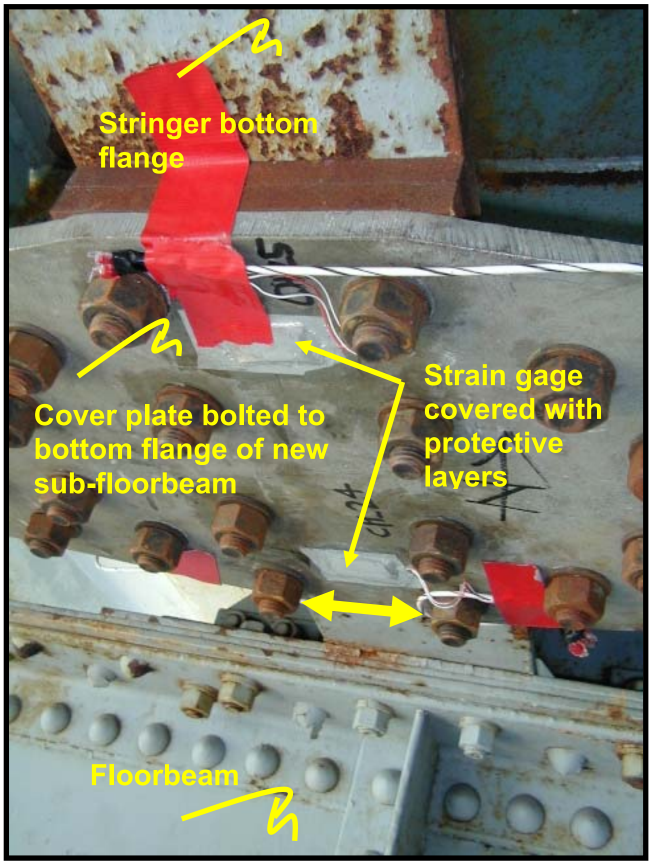


Figure 4.12 – Strain gages CH_24 and CH_25 were installed on the bottom cover plate bolted to the bottom flange of the new Sub-floorbeam8 in Span 36 (view from the bottom up)

4.1.13 Orthotropic Rib Web Plate

Strain gages were installed on the orthotropic rib web plate near the connection of the rib bearing plates to the sub-floorbeam upper flange to measure the out-of-plane bending stresses in the web plate, if any. The gages were installed in Span 35, 36, 38, and 45.

In Span 35, strain gages were installed on the east and west web plate of Rib 6 at the connection to Sub-floorbeam 2. Specifically, strain gages CH_50 and CH_51 were installed on the west web plate of Rib 6 on the south west and north west of the plate, respectively, at 2 in vertically from the bottom flange of the rib and approximately 4 1/2 in apart longitudinally (off of the centerline of the sub-floorbeam flange). On the east web plate of the same rib, strain gages CH_52 and CH_53 were installed on the south east and north east of the plate, respectively, at 2 in vertically from the bottom flange of the rib and approximately 4 1/2 in apart longitudinally (off of the centerline of the sub-floorbeam flange), where strain gage CH_52 was installed directly across from strain gage CH_50, and strain gage CH_53 was installed directly across from strain gage CH_51.

In Span 36, strain gages were installed on the east and west web plate of Rib6 at the connection to Sub-floorbeam 8. Specifically, strain gages CH_28 and CH_30 were installed on the west web plate of the rib on the south west and north west of the plate, respectively, at 2 in vertically from the bottom rib flange and approximately 4 1/2 in apart longitudinally (off of the centerline of the sub-floorbeam flange). On the east web plate of the same rib, strain gages CH_29 and CH_31 were installed on the south east and north east of the web plate, respectively, at 2 in vertically from the bottom rib flange and approximately 4 1/2 in apart (off of the centerline of the sub-floorbeam flange), where strain gage CH_29 was installed directly across from strain gage CH_28, and strain gage CH_31 was installed directly across from strain gage CH_30.

In Span 38, the strain gages were installed on the east and west web plate of Rib6 at the connection to Sub-floorbeam 2. Specifically, strain gages CH_55 and CH_56 were installed on the west web plate of the rib on the south west and north west of the plate, respectively, at 2 in vertically from the bottom flange of the rib and approximately 4 1/2 in apart longitudinally (off of the centerline of the sub-floorbeam flange). On the east web plate of the same rib, strain gages CH_57 and CH_58 were installed on the north east and south east of the web plate, respectively, at 2 in vertically from the bottom rib flange and approximately 4 1/2 in apart, where strain gage CH_57 was installed directly across from strain gage CH_56, and strain gage CH_58 was installed directly across from strain gage CH_55.

In Span 45, the strain gages were installed on the east and west web plate of Rib6 at the connection to Sub-floorbeam 2. Specifically, strain gages CH_25 and CH_27 were installed on the west web plate of the rib on the south west and north west of the plate, respectively, at 2 in vertically from the bottom rib flange and approximately 4 1/2 in apart, longitudinally (off of the centerline of the sub-floorbeam flange). On the east web plate of the same rib, strain gages CH_26 and CH_28 were installed on the south east and north east of the web plate respectively, at 2 in vertically from the bottom rib flange and approximately 4 1/2 in apart (Figure 4.13), where strain gage CH_26 was installed directly across from strain gage CH_25, and strain gage CH_28 was installed directly across from strain gage CH_27.

It is important to note that prior to installing the gages in Span 36 and Span 45, the keeper blocks, which were used as part of the prototype retrofit, were removed such that the strain gages could be installed. A small portion of the keeper blocks was ground slightly before they were put back in place to prevent them from pushing against the installed strain gages.

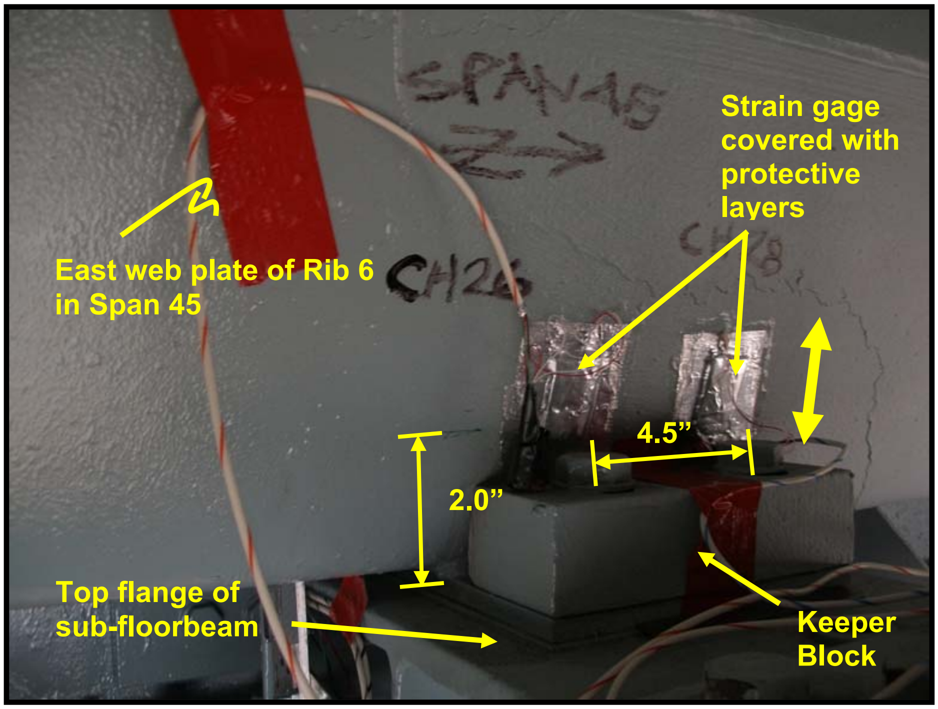


Figure 4.13 – Strain gages CH_26 and CH_28 installed in Span 45 at Sub-floorbeam 2-to-rib connection on the east web plate of rib 6 at 2 in vertically from the bottom flange of the rib and approximately 4 1/2 in apart
(view looking west)

4.2 Sensors for Displacement Measurements

Linear position sensors were installed at various locations on the spans to measure the local displacement at various details and characterize the global behavior of the bridge. Below is a discussion on the location of the displacement sensors and their purpose.

4.2.1 Longitudinal Displacement between the Main East Girder and the Deck

Displacement sensors were installed to measure the relative longitudinal displacement between the top flange of the east girder and the steel deck. The sensors were installed in all five spans to assess the effectiveness of the prototype shear connectors installed in Span 34, 36, and 45 in reducing the relative displacement between the girder and the steel deck when compared to Span 35 and Span 38 where prototype shear connectors were not installed.

The sensor device was mounted to a wooden block, which was bonded to the bottom face of the deck plate with epoxy. A bracket consisting of a built up steel angle sections, was secured to the top flange of the girder and used as target for the sensor such that the relative displacement between the steel deck and the top flange of the girder can be measured. Figure 4.14 shows an example of CH_57 installed at the north end of Span 35

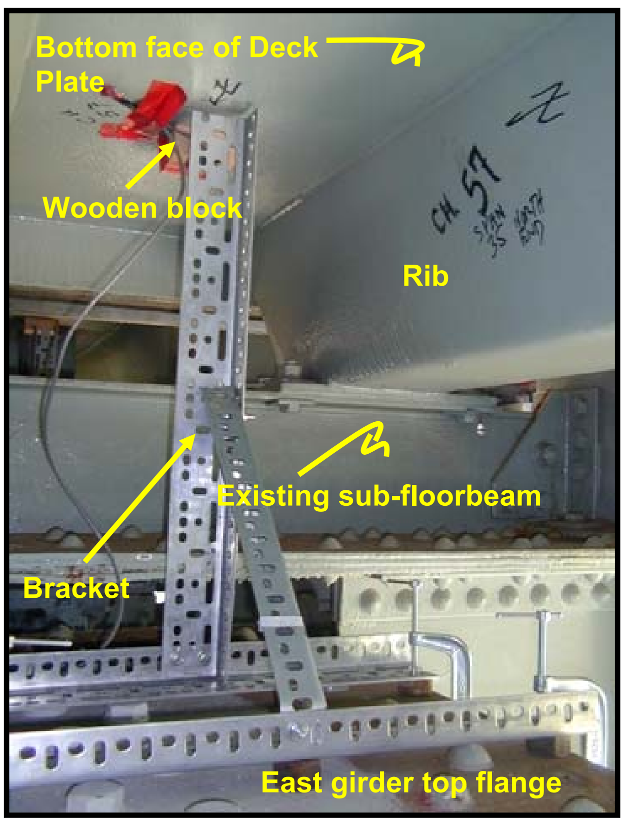


Figure 4.14 – Displacement sensor CH_37 installed in Span 35 to measure relative longitudinal displacement between the top flange of the east girder and the deck plate

As mentioned above, displacement sensors were installed in all five spans. Specifically, CH_1 and CH_30 were installed at the south and north end, respectively, of Span 34; CH_31 and CH_57 were installed at the south and north end, respectively, of Span 35; CH_36 and CH_1 were installed at the south and north end, respectively, of Span 36; CH_39 and CH_62 were installed at the south and north end, respectively of Span 38; CH_1 and CH_40 were installed at the south and north end respectively of Span 45.

4.2.2 Displacement at New and Existing Sub-floorbeam-to-Stringer Connection

Displacement sensors were installed in all five spans to measure the relative longitudinal displacement along the stringer between the new and the existing sub-floorbeam and the stringer at their connection.

In Span 34, CH_17 was installed to measure the relative displacement between the web of existing Sub-floorbeam 8 and Stringer 3. In Span 35, CH_43 was installed to measure the relative displacement between the web of existing Sub-floorbeam 2 and Stringer 3. In Span 36, CH_19 was installed to measure the relative displacement between the web of new Sub-floorbeam 8 and Stringer 3 (Figure 4.15). In Span 38, CH_47 was installed to measure the relative displacement between the web of new Sub-floorbeam 2 and Stringer 3. In Span 45, CH_18 was installed to measure the relative displacement between the web of new Sub-floorbeam 2 and Stringer 3.

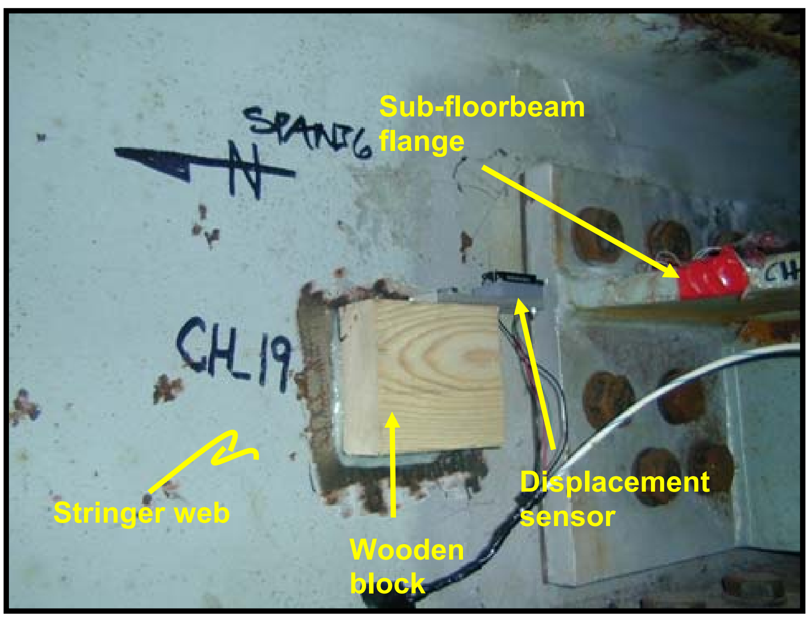


Figure 4.15 – Displacement sensor CH_19 installed in Span 36 to measure the relative displacement between the web of Sub-floorbeam 8 and Stringer 3.

4.2.3 Displacement between Bottom Flange of Rib Plate and New and Existing Sub-floorbeam

Rotation of the orthotropic rib with respect to the existing sub-floorbeam, because of the lack of proper shimming, has been identified as the cause of cracking in the trough rib strap plate located between the top face of the top flange of the existing sub-floorbeam and the bottom flange of the orthotropic rib. To measure such rotation and to assess the global deformation of the detail as well as the effectiveness of the prototype retrofits on minimizing the rotation, displacement sensors were installed to measure the vertical displacement between the bottom flange of the rib plate and the new and existing sub-floorbeams.

In Span 34, displacement sensors CH_19 and CH_20 were installed at the south and north side, respectively, of the existing Sub-floorbeam 8 to measure the vertical deflection of the flange of Rib 5 with respect to the sub-floorbeam. Similarly, displacement sensors CH_21 and CH_22 were installed at the south and north side, respectively, of the existing Sub-floorbeam 8 to measure the vertical deflection of the flange of Rib 6 with respect to the sub-floorbeam.

In Span 35, CH_48 was installed at the north side of the existing Sub-floorbeam 2 to measure the vertical deflection of the flange of Rib 5 with respect to the sub-floorbeam. Similarly, CH_49 was installed at the north side of the existing Sub-floorbeam 2 to measure the vertical deflection of the flange of Rib 6 with respect to the sub-floorbeam.

In Span 36, CH_32 was installed at the north side of the existing Sub-floorbeam 8 to measure the vertical deflection of the flange of Rib 5 with respect to the sub-floorbeam. Similarly, CH_27 was installed at the north side of the existing Sub-floorbeam8 to measure the vertical deflection of the flange of Rib 6 with respect to the sub-floorbeam.

In Span 38, CH_53 was installed at the south side of the existing Sub-floorbeam 2 to measure the vertical deflection of the flange of Rib 5 with respect to the sub-floorbeam. Similarly, CH_54 was installed at the south side of the existing Sub-floorbeam 2 to measure the vertical deflection of the flange of Rib 6 with respect to the sub-floorbeam.

In Span 45, CH_23 (Figure 4.16) was installed at the south side of the existing Sub-floorbeam 2 to measure the vertical deflection of the flange of Rib 5 with respect to the sub-floorbeam. Similarly, CH_24 was installed at the south side of the existing Sub-floorbeam 2 to measure the vertical deflection of the flange of Rib 6 with respect to the sub-floorbeam.

The installation of the displacement sensor at the new sub-floorbeam (Span 36 and Span 45) required the use of a mounting bracket as shown in Figure 4.16. The bracket was clamped to the vertical stiffeners welded to the web of the sub-floorbeam and located directly below the rib. Wooden blocks, glued to the sub-floorbeam web, were used for displacement sensor installation at the existing sub-floorbeam (Span 34, 35, and 38).

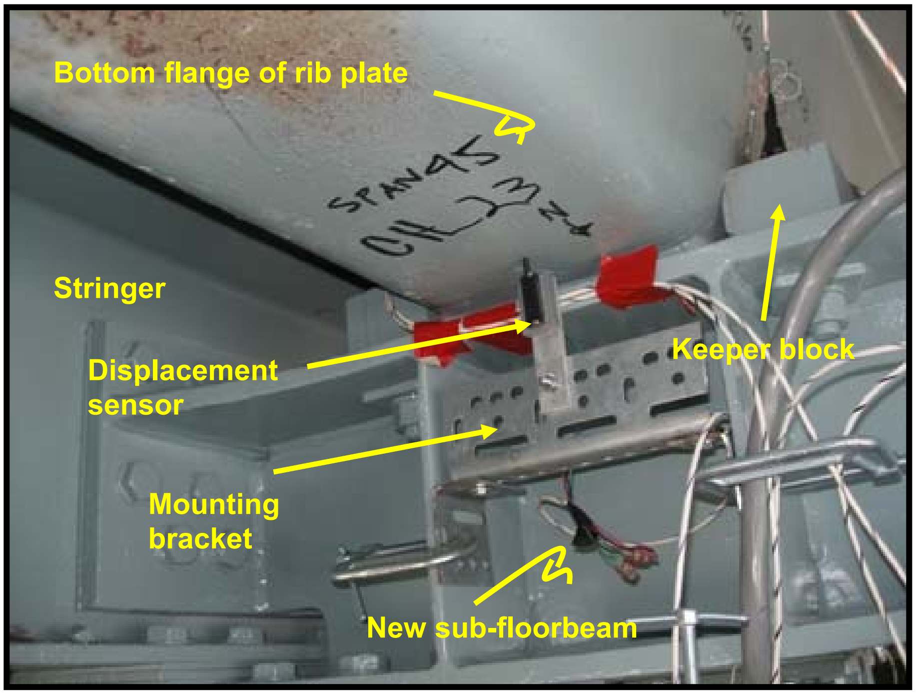


Figure 4.16 – Displacement sensor CH_23 installed in Span 45 to measure the relative displacement between the bottom flange of the rib plate and the new sub-floorbeam

4.2.4 Relative Displacement between the Bottom Flange of the Stringer and the Top Flange of the Floorbeam

Displacement sensors were installed to measure the degree of fixity at the floorbeam-to-stringer connection. The sensor was mounted to a wooden block, which was glued to the bottom face of the bottom flange of the stringer. The flange tip of the floorbeam was used as a target for the sensor such that the relative longitudinal displacement between the bottom flange of the stringer and the top flange of the floorbeam can be measured. The response of the details to controlled and random loads was used by PTG for the calibration of their finite element model of the spans.

Displacement sensors CH_38, CH_43, and CH_14 were installed in Span 35, 38, and 45, respectively, to measure the relative displacement between the bottom flange of Stringer 4 and Floorbeam 2. Similarly, in Span 36, CH_15 was installed to measure the relative displacement between the bottom flange of Stringer 4 and Floorbeam 8. Figure 4.17 shows displacement sensor CH_43 installed in Span 35.

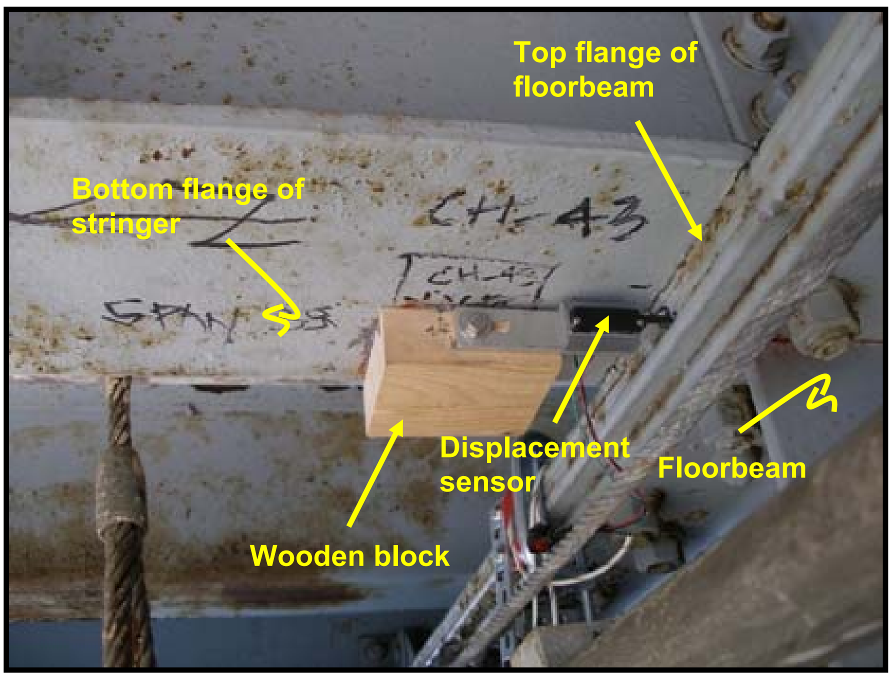


Figure 4.17 – Displacement sensor CH_43 installed in Span 35 to measure the relative displacement between the bottom flange of the stringer and the top flange of the floorbeam

4.2.5 Relative Displacement between the Web and the Flange of the Floorbeam

As previously stated, prototype retrofits of the web of the two end floorbeams were installed in Span 35, 36, and 45 and included bolting a WT-section to the web of the floorbeam to increase the cross sectional area of the web at that location and reduce the out-of-plane stresses on the web induced by the lateral bracing system. Displacement sensors were installed to measure the relative longitudinal displacement between the web and the flange of the floorbeam, which is a measure of the effectiveness of the retrofit in reducing the out-of-plane stresses. In addition, displacement sensors were installed on the web of Floorbeam 8 in Span 34 (no floorbeam retrofit, only shear connectors) and the web of Floorbeam 2 in Span 38 (no retrofits, the control span), such that a general comparison could be made between the effect of the shear connectors alone (Span 34), the effect of the floorbeam retrofit alone (Span 35), the effect of the complete retrofit (Span 36 and Span 45), and the effect of no retrofit (Span 38).

The displacement sensors included CH_11 in Span 34 at Floorbeam 8, CH_37 in Span 35 at Floorbeam 2, CH_14 in Span 36 at Floorbeam 8, CH_42 in Span 38 (no retrofit, control span) at Floorbeam 2, and CH_16 in Span 45 at Floorbeam 2. Figure 4.18 shows displacement sensor CH_14 installed in Span 36 to measure the relative displacement between the web and the flange of Floorbeam 8.

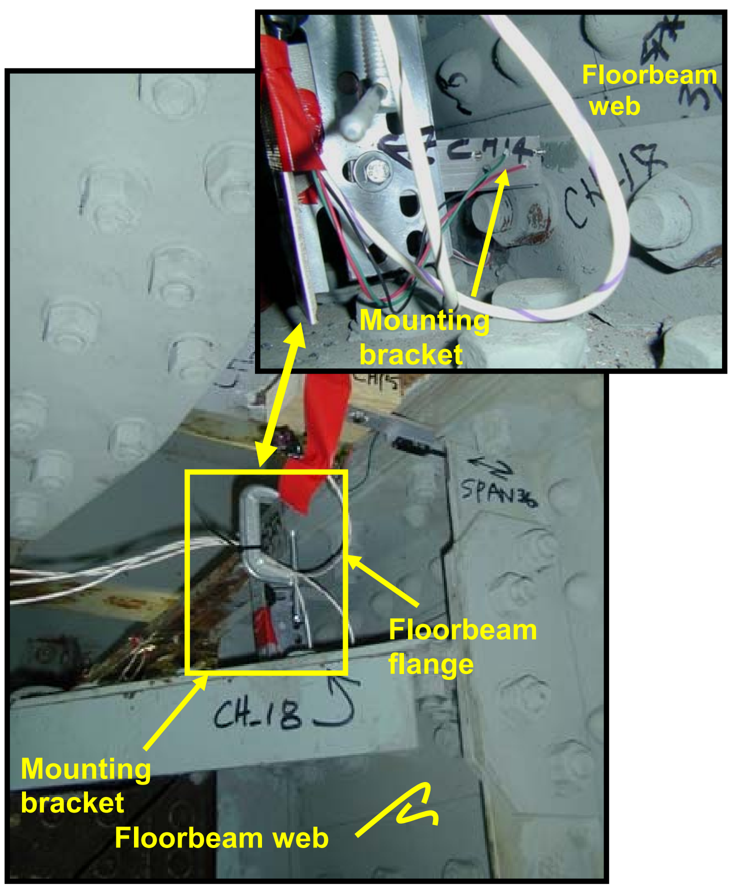


Figure 4.18 – Displacement sensor CH_14 installed in Span 36 to measure the relative displacement between floorbeam web and floorbeam flange

4.2.6 Displacement between the Top Flange of the Girder and the Bottom Flange of the Existing and New Sub-floorbeam

The relative longitudinal displacement between the top flange of the east girder and the new and existing sub-floorbeams was measured such that influence of the various prototype retrofits on the global behavior of the sub-floorbeams could be examined.

In Span 34, CH_18 was installed to measure the displacement between the top flange of the east girder and the existing Sub-floorbeam 8. In Span 35, CH_42 was installed to measure the displacement between the top flange of the east girder and the existing Sub-floorbeam 2. In Span 36, CH_26 was installed to measure the displacement between the top flange of the east girder and the new Sub-floorbeam 2. In Span 38, CH_52 was installed to measure the displacement between the top flange of the east girder and the existing Sub-floorbeam 2. In Span 45, CH_17 was installed to measure the displacement between the top flange of the east girder and the new Sub-floorbeam 2.

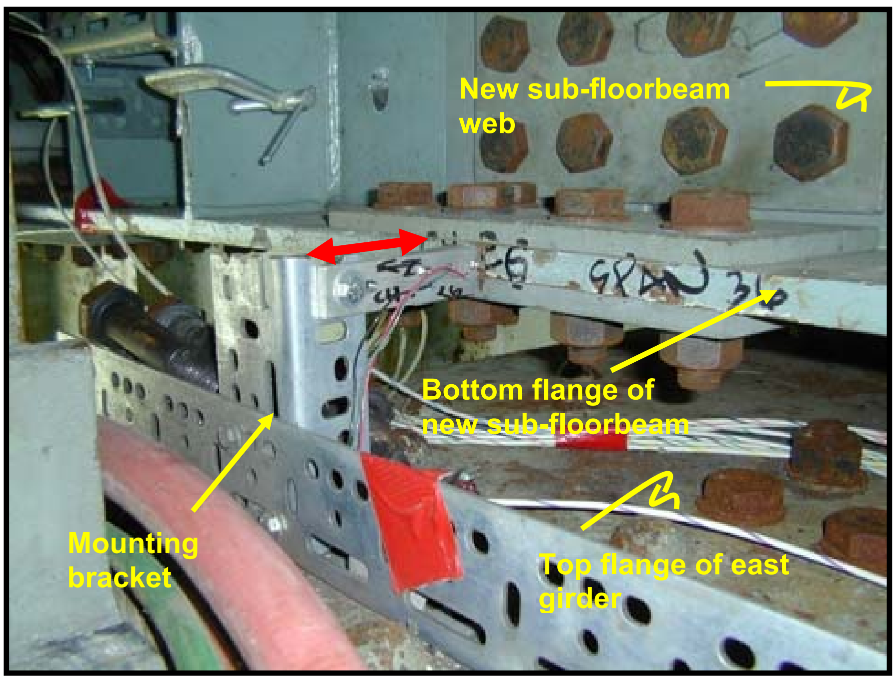


Figure 4.19 – Displacement sensor CH_26 installed on Span 36 to measure the relative displacement between the top flange of the main girder and the bottom flange of the new sub-floorbeam

4.2.7 Longitudinal Displacement between the Pier and the End of the Girder

Displacement sensors were installed to measure the longitudinal displacement between the pier and the east girder. Specifically, displacement sensors CH_36, CH_13, and CH_43 were installed to measure the relative displacement between Pier 34, Pier 36, and Pier 44, and the south end of the east girder in Span 35, the north end of the east girder in Span 36, the south end of the east girder in Span 45, respectively. The displacement sensors were installed to assess the global response of the spans at the location of the pier. Figure 4.20 shows displacement sensor CH_36 installed in Span 35 to measure the relative displacement between Pier 34 and the east girder.

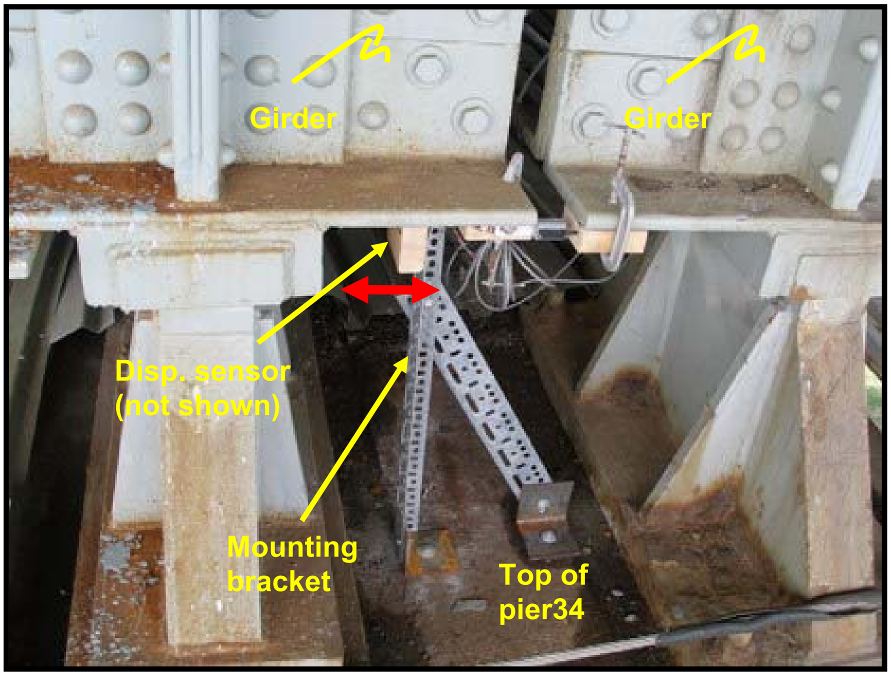


Figure 4.20 – CH_36 installed in Span 35 to measure the relative displacement between Pier 34 and the east girder

4.2.8 Relative Displacement between the Ends of the Girders

In addition to the displacement sensors installed to measure the longitudinal displacement between the pier and the east girder, displacement sensors were installed to measure the relative displacement between the top flanges and the bottom flange at the end of the east girders. Specifically, at Pier 34 displacement sensors CH_35 and CH_34 were installed to measure the relative displacement between the bottom flanges and the top flanges, respectively, of the north end of the east girder in Span 34 and the south end of the east girder in Span 35. At Pier 36 displacement sensors CH_12 and CH_11 were installed to measure the relative displacement between the bottom flanges and the top flanges, respectively, of the north end of the east girder in Span 36 and the south end of the east girder in Span 37. At Pier 44 displacement sensors CH_42 and CH_41 were installed to measure the relative displacement between the bottom flanges and the top flanges, respectively, of the north end of the east girder in Span 44 and the south end of the east girder in Span 45. Figure 4.21 shows CH_35 installed in Span 35 to measure the relative displacement between the bottom flanges of the east girders.

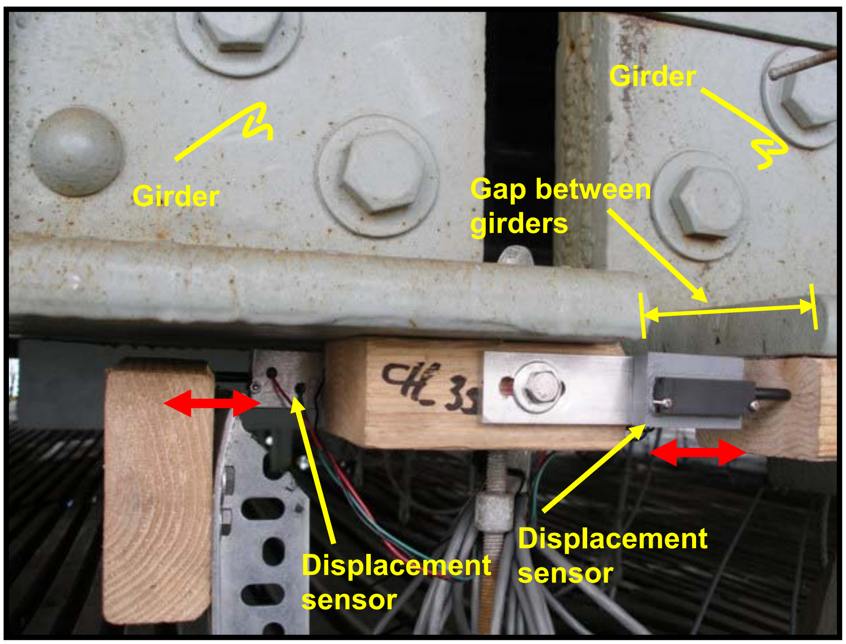


Figure 4.21 – Displacement sensor CH_35 installed in Span 35 to measure the relative displacement between the bottom flanges of the east girders

4.3 Thermocouples on Superstructure Elements

Thermocouples were installed on the bottom face of the deck plate and the top flange of the east girder to measure their ambient temperature. Below is a discussion on the location of the installed thermocouples and the purpose for the installation.

4.3.1 Thermocouples on Steel Deck Plate

Thermocouples CH_2, CH_32, CH_37, CH_40, and CH_2 were installed on the bottom face of the deck plate at the south end of Span 34, 35, 36, 38, and 45 to measure the variation in the deck plate temperature during the long-term monitoring period.

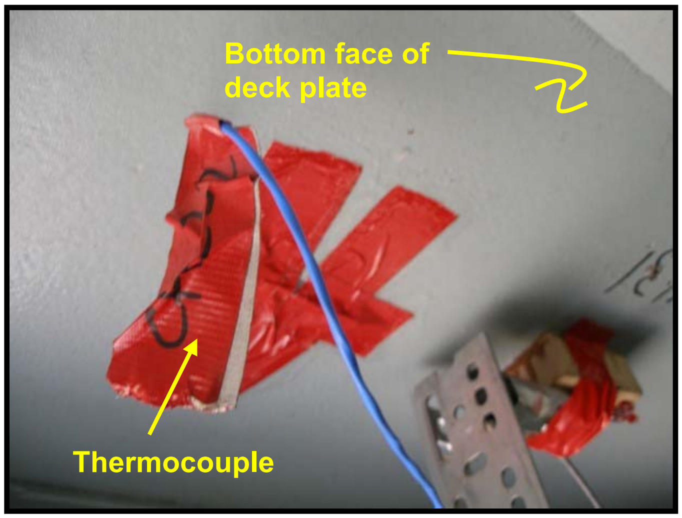


Figure 4.22 – Thermocouple CH_22 installed on the bottom deck plate of Span 35

4.3.2 Thermocouples on East Girder

Thermocouples CH_3, CH_33, CH_38, CH_41, and CH_3 were installed on the top flange of the east girder at the south end of Span 34, 35, 36, 38, and 45 to measure the variation in the deck plate temperature during the long-term monitoring period.

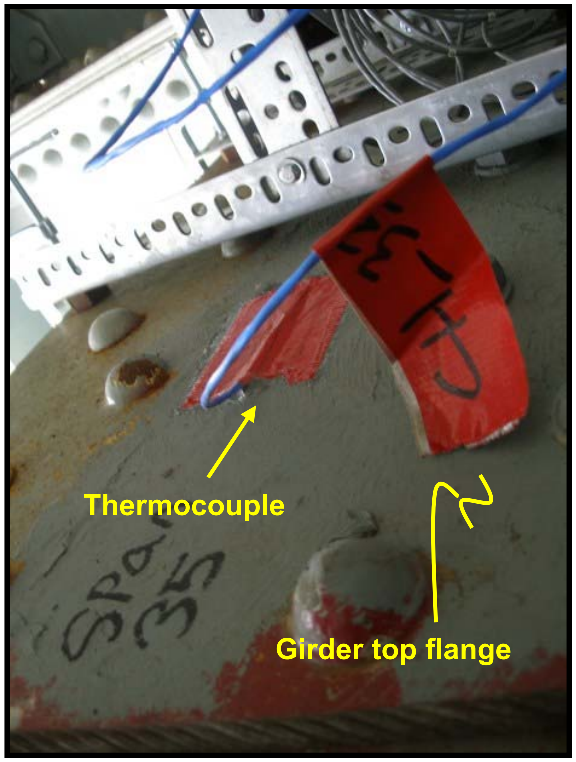


Figure 4.23 – Thermocouple CH_33 installed on the top flange of the east girder of Span 35

4.4 Accelerometers on East Girder

Accelerometers were installed in the vertical orientation at midspan of each of the five instrumented spans. It was desired to measure the vertical displacement of the primary girders under load during the controlled-load testing and long-term monitoring phases of this project. However, due to the fact that the spans are high above either ground or water, there is no point of reference to which a common displacement sensor (such as an LVDT) could be attached to. Other displacement measurement systems are either prohibitively expensive (such as laser) or do not have sufficient precision (such as GPS). As an alternative, it was proposed to use accelerometers to measure the vertical accelerations of the girders at midspan. If the speed of the loading is rapid enough, it may be possible to integrate the acceleration time-history twice to obtain the displacement history.

The accelerometers used for this project are a "capacitive" type of accelerometer which outputs a voltage in direct proportion to the acceleration experienced by the sensor. Unlike some other accelerometer types, these accelerometer measure accelerations with frequencies down to 0 Hz, i.e., static acceleration, with a maximum frequency response of 100 Hz. When oriented vertically, the sensor outputs 1 g, while in the horizontal orientation, it outputs 0 g. Furthermore, these accelerometers have very high sensitivity (1 V/g) and high resolution (30 μg) which is useful when measuring low frequency accelerations on bridges which typically have low acceleration amplitudes.

A photograph of an accelerometer as installed at midspan of the east girder of Span 45 is shown in Figure 4.24. The accelerometer is pre-bolted to a mounting angle. This assembly is wrench clamped to the vertical stiffener at midspan. Note that the accelerometer is oriented in the vertical direction.

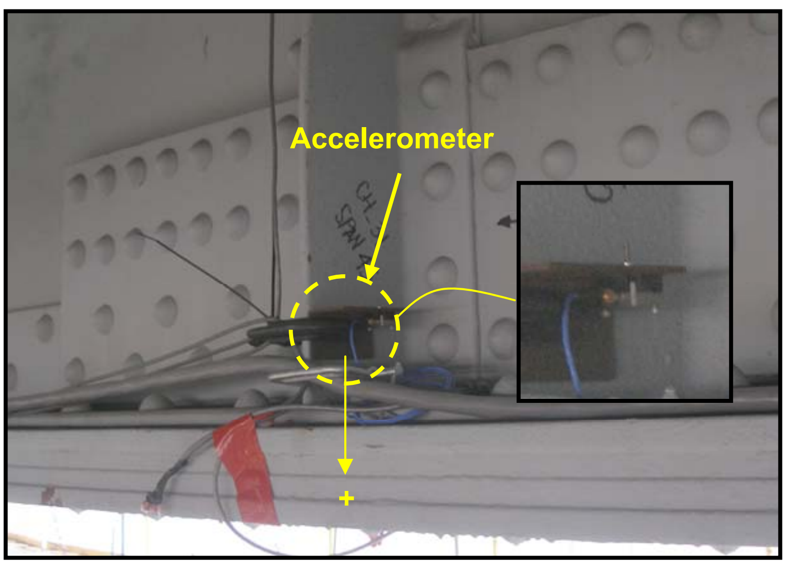


Figure 4.24 – Accelerometer CH_31 installed in Span 45 at midspan of the east girder

5.0 Results of Controlled Load Tests

The results of the controlled static and dynamic load tests are discussed in this section.

5.1 General Response

In general, the global response of the spans was as expected and typical of a simple span bridge. Figure 5.1 presents the response of strain gages CH_33 and CH_34 installed on the top and bottom flange, respectively, of the east girder in Span 36, approximately 4 in north of midspan during the crawl test CRL1_36. The six peaks shown in the figure represent the northbound passage of Truck 1 in the right lane (first peak), followed by Truck 2 in the same lane (second peak), followed by Truck 3 in the middle lane (third peak), followed by Truck 4 also in the middle lane (fourth peak), followed by Truck 5 in the left lane (fifth peak), and finally Truck 6 also in the left lane (sixth peak). The time separating the passage of each test truck was approximately 1.5 to 3 minutes. The response of the strain gages to random southbound traffic was also recorded during the tests since the bridge was open to southbound traffic while the tests were being conducted (northbound traffic was temporarily stopped during the tests). Figure 5.1 shows the response of strain gages CH_33 and CH_34 to random traffic, which is represented by the scattered events shown between the six major peaks discussed above.

As shown in the figure, and as expected, tensile stresses were measured in the bottom flange of the girder while compressive stresses were measured in the top flange. The figure also shows that the response of the girder is at maximum when the test truck crossed in the right lane directly over the gages (first and second peak). The response in the gages decreased as the tests trucks crossed over the middle lane (third and fourth peak) and decreased further when the test truck crossed over the left lane (fifth and sixth peak). It is important to note that Figure 5.1 shows that the stress in the bottom flange is approximately twice the absolute magnitude of the stress in the top flange. This is also the case for the gages installed at similar locations in Span 34 and Span 45. Span 34, Span 36, and Span 45 are similar in that prototype shear connectors were installed at the north and south end of the spans. The shear connectors appear to have introduced a composite action between the main girder and the steel deck, which resulted in an upward shifting of the neutral axis of the deck-girder system and hence, a lowering of the response in the top flange. Prototype shear connectors were, however, not installed in Span 35 and Span 38. No difference in the magnitude of the stresses was observed in the gages installed on the east girder of these two spans (35 and 38) at similar locations to those described above in Span 34, Span 36, and Span 45, indicating that the presence of the shear connectors had an effect on the measured flange stresses by shifting the neutral axis upward. Figure 5.2 shows the response in gages CH_59 & CH_60 installed on the top and bottom flange, respectively, of the east girder in Span 38, approximately 4 in north of midspan in the crawl test CRL1_36. The figure clearly shows that the response in the top and bottom flange of the girder is almost identical, which was expected since the prototype shear connectors were not installed in this span.

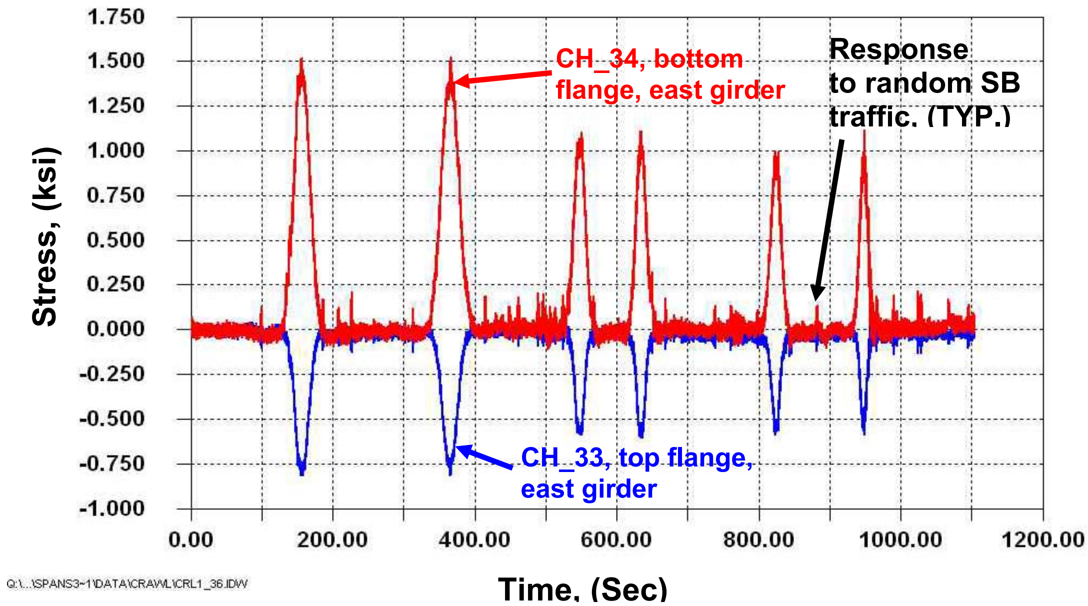


Figure 5.1 – Response of strain gages CH_33 & CH_34 installed on the top and bottom flange, respectively, of the east girder in Span 36, approximately 4 in north of midspan as the test trucks crossed in the northbound direction over all three lanes in the crawl test CRL1_36.

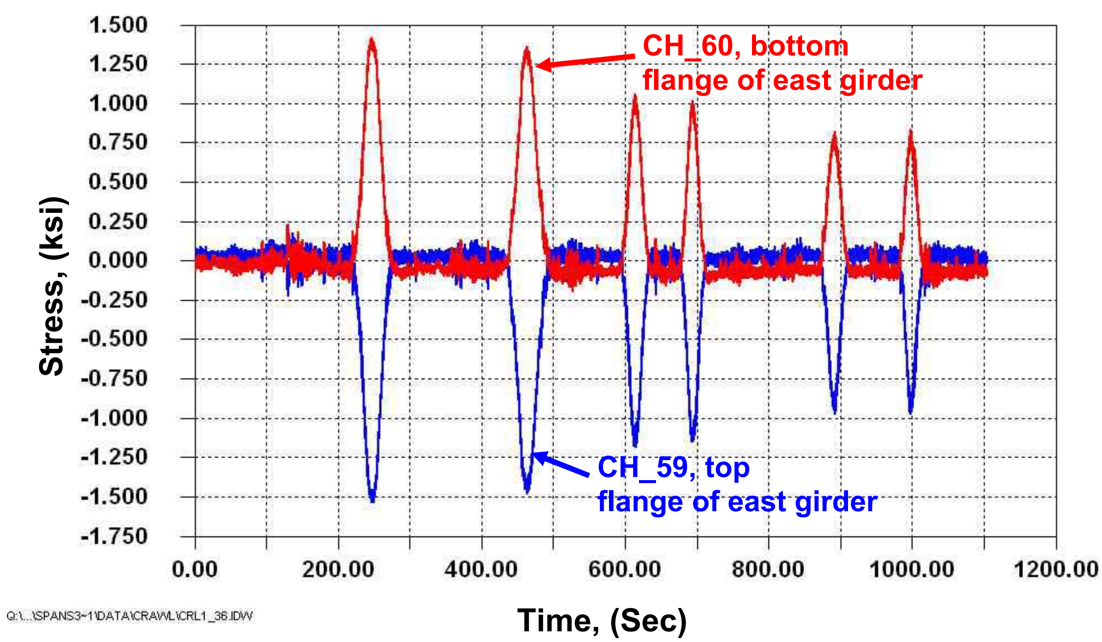


Figure 5.2 – Response of strain gages CH_59 & CH_60 installed on the top and bottom flange, respectively, of the east girder in Span 38, approximately 4 in north of midspan as the test trucks crossed in the northbound direction over all three lanes in the crawl test CRL1_36.

5.2 Repeatability of Data

All crawl tests were repeated twice except in the multiple presence crawl test where all test trucks traveled side-by-side in all six lanes. Dynamic tests were repeated with test trucks traveling in the same lanes, but with different speed however. As previously noted, in a given test where one, two, or three test trucks were utilized in the test, the test was repeated with the same number of test truck(s) passing over the same lane and approximately 1.5 to 3 minutes apart. For example, in the crawl test (CRL34_1), Truck 1 crossed over Span 34 in the outside lane. Approximately 1 1/2 minutes after the passage of Truck 1 in the outside lane over the span (i.e., Truck 1 is off Span 34), the test was repeated with Truck 2 passing in the same lane in the same span. The weight of the test trucks passing over a given lane in any repeated test were not exactly the same (approximately 11% maximum weight difference between trucks). However, this variation appears not to have significant impact on the shape of the curves representing the overall stress time history response. However, some variation in the magnitude of the measured stresses was observed in some of the gages in the repeated test. This could be attributed to the fact that all six trucks used in the controlled load tests did not have the exact same weight or axle spacing, the bridge was opened to random southbound traffic while the tests were being conducted, and the fact that some gages exhibited high localized response as the test truck(s) crossed over the strain gaged locations. These strain gages also appear to be highly sensitive to the transverse location of the test truck as discussed below. Although the overall location of the test trucks in repeated tests was the same (i.e., the trucks were traveling in the same lane in the repeated test), the exact transverse position of the test truck in repeated tests could have varied slightly within the lane.

It is important to note that the response in the main girders was almost identical within repeated tests despite the fact that the weight of the trucks used in the tests were different and the bridge was opened to southbound traffic while testing. This can be seen in Figure 5.1 where the first two peaks representing the crossing of Truck 1 followed by the crossing of Truck 2, respectively, over Span 36 in the right lane is almost identical (the same is true for the third and fourth peak, and the fifth and sixth peak). Similar observation can be made as shown in Figure 5.2.

5.3 Results of Crawl Tests

5.3.1 Stresses in the Riveted Main East Girder Flange

As previously discussed, strain gages were installed near midspan (4’-0” north of midspan) on the top and bottom flange of the east girder in each of the five instrumented spans. Strain gages CH_4 and CH_5 were installed on the top and bottom flange, respectively, of the east girder in Span 34. Strain gages CH_54 and CH_55 were installed on the top and bottom flange, respectively, of the east girder in Span 35. Strain gages CH_33 and CH_34 were installed on the top and bottom flange, respectively, of the east girder in Span 36. Strain gages CH_59 and CH_60 were installed on the top and bottom flange, respectively, of the east girder in Span 38. Strain gages CH_29 and CH_30 were installed on the top and bottom flange, respectively, of the east girder in Span 45. Because of the lack of access to the bottom face of the bottom flange of the east girder in span 38, strain gage CH_60 was installed on the top face of the bottom flange at approximately 1 in from the edge of the flange. All other gages were installed at mid width of the flange, on the top face of the top flange and/or the bottom face of the bottom flange.

The riveted flange is classified as Category D detail per the AASHTO Specifications with constant amplitude fatigue limit (CAFL) of 7 ksi. Figure 5.1 presents the response of strain gages CH_33 and CH_34 installed on the top and bottom flange, respectively, of the east girder in Span 36, approximately 4 in north of midspan as the test trucks crossed over all three lanes in the northbound direction in the crawl test CRL1_36. Summaries of the maximum stress, minimum stress, and stress range values experienced by the gages in all crawl tests, including the multiple presence truck test are presented in Tables 5.1 through 5.5 (one table for each of the five instrumented spans). *(Note: in all tables listed below, the abbreviation "O.L" means outside lane, the abbreviation "M.L" means middle lane, and the abbreviation "I.L" means inside lane. These abbreviations are used in all tables and will not be explained further).*

Span 34, top and bottom flange of east girder, 4ft north of midspan							
Test name	Truck in lane	CH_5, (ksi)			CH_4, (ksi)		
		σ_{max}	σ_{min}	$\Delta\sigma$	σ_{max}	σ_{min}	$\Delta\sigma$
CRL1_34	Truck 1, (O.L)	1.1	0.0	1.1	0.0	-0.7	0.7
	Truck 2, (O.L)	1.1	0.0	1.1	0.0	-0.7	0.7
	Truck 3, (M.L)	0.9	0.0	0.9	0.0	-0.5	0.5
	Truck 4, (M.L)	0.9	0.0	0.9	0.0	-0.5	0.5
	Truck 5, (I.L)	0.7	0.0	0.7	0.0	-0.5	0.5
	Truck 6, (I.L)	0.7	0.0	0.7	0.0	-0.5	0.5
CRL2_34	Truck 1, (O.L)& Truck 2, (M.L)	2.2	0.0	2.2	0.0	-1.2	1.2
	Truck 3, (OL)& Truck 4, (ML)	2.0	0.0	2.0	0.0	-1.1	1.1
CRL3_34	Truck 5, (M.L)& Truck 6, (I.L)	2.0	0.0	2.0	0.0	-1.1	1.1
	Truck 1, (ML)& Truck 2, (IL)	1.9	0.0	1.9	0.0	-1.0	1.0
CRL4_34	Truck 3, (OL)& Truck 4, (ML) &Truck 5, (IL)	2.9	0.0	2.9	0.0	-1.5	1.5
	Truck 6, (O.L)& Truck 1, (M.L) &Truck 2, (I.L)	3.0	0.0	3.0	0.0	-1.6	1.6
M_34	Multiple presence	3.3	0.0	3.3	0.0	-1.9	1.9

Table 5.1 – Summary of peak stresses (ksi) measured in strain gages CH_4 and CH_5 installed on the top and bottom flange, respectively, of the east girder in Span 34, approximately 4 in north of midspan as the test trucks crossed over the span in the northbound direction in the crawl tests

Span 35, top and bottom flange of east girder, 4ft north of midspan							
Test name	Truck in lane	CH_55, (ksi)			CH_54, (ksi)		
		σ_{max}	σ_{min}	$\Delta\sigma$	σ_{max}	σ_{min}	$\Delta\sigma$
CRL1_34	Truck 1, (O.L)	1.6	0.0	1.6	0.0	-1.4	1.4
	Truck 2, (O.L)	1.6	0.0	1.6	0.0	-1.4	1.4
	Truck 3, (M.L)	1.3	0.0	1.3	0.0	-1.1	1.1
	Truck 4, (M.L)	1.2	0.0	1.2	0.0	-1.0	1.0
	Truck 5, (I.L)	1.0	0.0	1.0	0.0	-0.9	0.9
	Truck 6, (I.L)	0.9	0.0	0.9	0.0	-0.9	0.9
CRL2_34	Truck 1, (O.L)& Truck 2, (M.L)	2.7	0.0	2.7	0.0	-2.4	2.4
	Truck 3, (OL)& Truck 4, (ML)	2.5	0.0	2.5	0.0	-2.3	2.3
CRL3_34	Truck 5, (M.L)& Truck 6, (I.L)	2.3	0.0	2.3	0.0	-2.0	2.0
	Truck 1, (ML)& Truck 2, (IL)	2.3	0.0	2.3	0.0	-2.0	2.0
CRL4_34	Truck 3, (OL)& Truck 4, (ML) &Truck 5, (IL)	3.5	0.0	3.5	0.0	-2.9	2.9
	Truck 6, (O.L)& Truck 1, (M.L) &Truck 2, (I.L)	3.7	0.0	3.7	0.0	-3.3	3.3
M_34	Multiple presence	4.0	0.0	4.0	0.0	-3.3	3.3

Table 5.2 – Summary of peak stresses (ksi) measured in strain gages CH_54 and CH_55 installed on the top and bottom flange, respectively, of the east girder in Span 35, approximately 4 in north of midspan as the test trucks crossed over the span in the northbound direction in the crawl tests

Span 36, top and bottom flange of east girder, 4ft north of midspan							
Test name	**Truck in lane**	**CH_34, (ksi)**			**CH_33, (ksi)**		
		σ_{max}	σ_{min}	$\Delta\sigma$	σ_{max}	σ_{min}	$\Delta\sigma$
CRL1_36	**Truck 1, (O.L)**	1.5	0.0	1.5	0.0	-0.8	0.8
	Truck 2, (O.L)	1.5	0.0	1.5	0.0	-0.8	0.8
	Truck 3, (M.L)	1.1	0.0	1.1	0.0	-0.6	0.6
	Truck 4, (M.L)	1.1	0.0	1.1	0.0	-0.6	0.6
	Truck 5, (I.L)	1.0	0.0	1.0	0.0	-0.6	0.6
	Truck 6, (I.L)	1.0	0.0	1.0	0.0	-0.6	0.6
CRL2_36	**Truck 1, (O.L)& Truck 2, (M.L)**	2.6	0.0	2.6	0.0	-1.4	1.4
	Truck 3, (OL)& Truck 4, (ML)	2.5	0.0	2.5	0.0	-1.3	1.3
CRL3_36	**Truck 5, (M.L)& Truck 6, (I.L)**	2.1	0.0	2.1	0.0	-1.2	1.2
	Truck 1, (ML)& Truck 2, (IL)	1.9	0.0	1.9	0.0	-1.1	1.1
CRL4_36	**Truck 3, (OL)& Truck 4, (ML) &Truck 5, (IL)**	3.1	0.0	3.1	0.0	-1.8	1.8
	Truck 6, (O.L)& Truck 1, (M.L) &Truck 2, (I.L)	3.6	0.0	3.6	0.0	-2.0	2.0
M_36	**Multiple presence**	3.8	0.0	3.8	0.0	-2.0	2.0

Table 5.3 – Summary of peak stresses (ksi) measured in strain gages CH_33 and CH_34 installed on the top and bottom flange, respectively, of the east girder in Span 36, approximately 4 in north of midspan as the test trucks crossed over the span in the northbound direction in the crawl tests

Span 38, top and bottom flange of east girder, 4ft north of midspan							
Test name	**Truck in lane**	**CH_60, (ksi)**			**CH_59, (ksi)**		
		σ_{max}	σ_{min}	$\Delta\sigma$	σ_{max}	σ_{min}	$\Delta\sigma$
CRL1_36	**Truck 1, (O.L)**	1.4	0.0	1.4	0.0	-1.5	1.5
	Truck 2, (O.L)	1.3	0.0	1.3	0.0	-1.5	1.5
	Truck 3, (M.L)	1.0	0.0	1.0	0.0	-1.2	1.2
	Truck 4, (M.L)	1.0	0.0	1.0	0.0	-1.1	1.1
	Truck 5, (I.L)	0.8	0.0	0.8	0.0	-1.0	1.0
	Truck 6, (I.L)	0.8	0.0	0.8	0.0	-1.0	1.0
CRL2_36	**Truck 1, (O.L)& Truck 2, (M.L)**	2.8	0.0	2.8	0.0	-2.4	2.4
	Truck 3, (OL)& Truck 4, (ML)	2.4	0.0	2.4	0.0	-2.5	2.5
CRL3_36	**Truck 5, (M.L)& Truck 6, (I.L)**	2.1	0.0	2.1	0.0	-2.3	2.3
	Truck 1, (ML)& Truck 2, (IL)	1.8	0.0	1.8	0.0	-1.9	1.9
CRL4_36	**Truck 3, (OL)& Truck 4, (ML) &Truck 5, (IL)**	3.0	0.0	3.0	0.0	-3.4	3.4
	Truck 6, (O.L)& Truck 1, (M.L) &Truck 2, (I.L)	3.3	0.0	3.3	0.0	-3.6	3.6
M_36	**Multiple presence**	3.8	0.0	3.8	0.0	-3.9	3.9

Table 5.4 – Summary of peak stresses (ksi) measured in strain gages CH_59 and CH_60 installed on the top and bottom flange, respectively, of the east girder in Span 38, approximately 4 in north of midspan as the test trucks crossed over the span in the northbound direction in the crawl tests

Span 45, top and bottom flange of east girder, 4ft north of midspan							
Test name	Truck in lane	CH_30, (ksi)			CH_29, (ksi)		
		σ_{max}	σ_{min}	$\Delta\sigma$	σ_{max}	σ_{min}	$\Delta\sigma$
CRL1_45	Truck 1, (O.L)	1.6	0.0	1.6	0.0	-0.8	0.8
	Truck 2, (O.L)	1.6	0.0	1.6	0.0	-0.7	0.7
	Truck 3, (M.L)	1.2	0.0	1.2	0.0	-0.6	0.6
	Truck 4, (M.L)	1.2	0.0	1.2	0.0	-0.6	0.6
	Truck 5, (I.L)	1.0	0.0	1.0	0.0	-0.5	0.5
	Truck 6, (I.L)	1.1	0.0	1.1	0.0	-0.5	0.5
CRL2_45	Truck 1, (O.L)& Truck 2, (M.L)	2.9	0.0	2.9	0.0	-1.3	1.3
	Truck 3, (OL)& Truck 4, (ML)	2.5	0.0	2.5	0.0	-1.2	1.2
CRL3_45	Truck 5, (M.L)& Truck 6, (I.L)	2.3	0.0	2.3	0.0	-1.2	1.2
	Truck 1, (ML)& Truck 2, (IL)	2.2	0.0	2.2	0.0	-1.1	1.1
[1]CRL4_45	Truck 3, (OL)& Truck 4, (ML) &Truck 5, (IL)	NA	NA	NA	NA	NA	NA
	Truck 6, (O.L)& Truck 1, (M.L) &Truck 2, (I.L)	NA	NA	NA	NA	NA	NA
M_45	Multiple presence	0.0	4.0	4.0	0.0	-1.9	1.9

Note:
1. Data for this test were not retrieved

Table 5.5 – Summary of peak stresses (ksi) measured in strain gages CH_29 and CH_30 installed on the top and bottom flange, respectively, of the east girder in Span 45, approximately 4 in north of midspan as the test trucks crossed over the span in the northbound direction in the crawl tests

5.3.2 Stresses in the Riveted Tie Plate

Strain gages were installed on the tie plates crossing transversely over the east girder. Specifically, in Span 34, strain gage CH_12 was installed on the east tie plate of Floorbeam 8, at the north edge of the plate. In Span 35, strain gages CH_39 and CH_40 were installed on the east tie plate of Floorbeam 2, at the south and north edge of the plate, respectively. In Span 36, strain gages CH_16 and CH_17 were installed on the east tie plate of Floorbeam 8, at the south and north edge of the plate, respectively. In Span 38, strain gages CH_45 and CH_46 were installed on the east tie plate of Floorbeam 2 at the south and north edge of the plate, respectively. In Span 45, strain gages CH_12 and CH_13 were installed on the east tie plate of Floorbeam 2 at the south and north edge of the plate, respectively. All gages were installed on the east tie plate at approximately 4 in west of the centerline of the girder and 1 in from the edge of the tie plate, except strain gages CH_16 and CH_17 installed in Span 36 on the tie plate at the centerline of the girder.

The gages were installed at the south and north edge of the tie plate to assess if out-of-plane stresses exist in the tie. If no out-of-plane bending stresses are present (i.e., only in-plane bending stresses), then both gages installed at the north and south edge of the tie should exhibit the same response. Figure 5.3 presents the response of strain gages CH_39 and CH_40 installed on the east tie plate of Floorbeam 2 in Span 35 during the passage of Truck 1 over the outside lane in the northbound direction in the crawl test CRL1_34. It is clear from the figure that the response of the gages is different, indicating that out-of-plane stresses are present in the tie plate. The out-of-plane stresses are not directly measured but could be calculated by subtracting the total stress measured by the gage from the in-plane stress (average stress of both gages).

This riveted detail is classified as Category D detail per AASHTO Specifications with constant amplitude fatigue limit (CAFL) of 7 ksi. Summaries of the maximum stress, minimum stress, and stress range values experienced by the gages in the crawl tests, including the multiple presence truck test are presented in Tables 5.6 through 5.10 (one table for each of the five instrumented spans). The tables show that the response of the strain gages installed in Span 34, 35, 36, and 45 is lower than the response measured by the gages installed in Span 38. Such observation suggests that the prototype retrofits installed on the spans reduced the out-of-plane displacement of the tie plate details. The maximum stress ranges measured by strain gages CH_12, CH_39, CH_40, CH_16, CH_17, CH_45, CH_46, CH_12, and CH_13 are 1.7 ksi, 1.9 ksi, 2.1 ksi, 3.0 ksi, and 2.0 ksi, respectively. At all instrumented locations, the maximum stress measured by any of the gages was less than the CAFL of the detail. The response of the riveted tie plates during the controlled load tests suggests that the prototype retrofit of the floorbeam web in Span 34, Span 35, Span 36, and Span 45 did not have significant effect on the behavior of the tie plates.

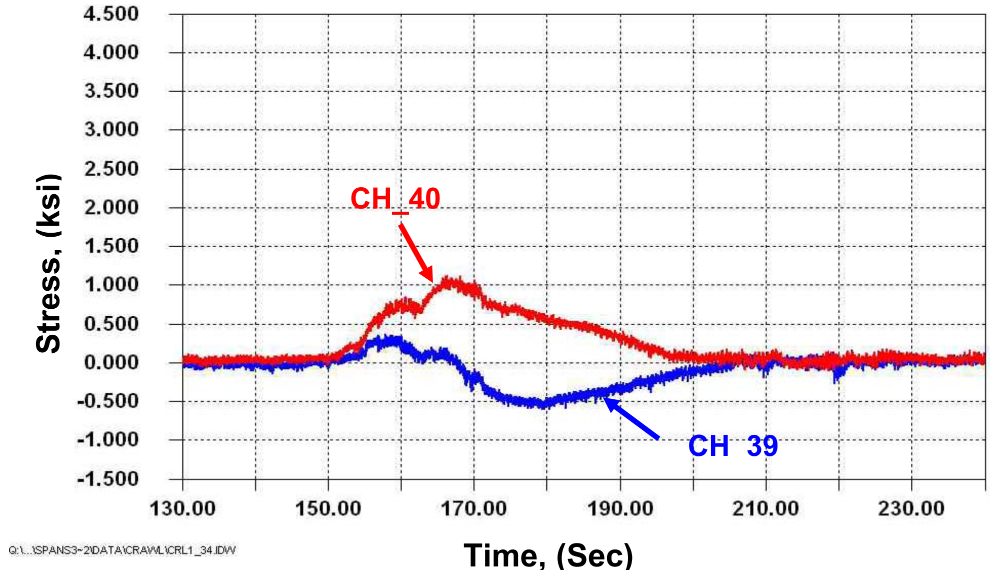


Figure 5.3 – Response of strain gages CH_39 and CH_40 installed on the east tie plate of Floorbeam 2 in Span 35 at approximately 4 in west to the centerline of the girder and 1 in from the edge of the tie plate as Truck 1 crossed in the northbound direction over the span in the outside lane during the crawl test CRL1_34.

Span 34, east tie plate of Floorbeam 8				
Test name	Truck in lane	CH_12, (ksi)		
		σ_{max}	σ_{min}	$\Delta\sigma$
CRL1_34	Truck 1, (O.L)	1.0	0.0	1.0
	Truck 2, (O.L)	1.0	0.0	1.0
	Truck 3, (M.L)	0.3	0.0	0.3
	Truck 4, (M.L)	0.4	0.0	0.4
	Truck 5, (I.L)	0.5	0.0	0.5
	Truck 6, (I.L)	0.5	0.0	0.5
CRL2_34	Truck 1, (O.L)& Truck 2, (M.L)	1.2	0.0	1.2
	Truck 3, (OL)& Truck 4, (ML)	1.1	0.0	1.1
CRL3_34	Truck 5, (M.L)& Truck 6, (I.L)	0.7	0.0	0.7
	Truck 1, (ML)& Truck 2, (IL)	0.6	0.0	0.6
CRL4_34	Truck 3, (OL)& Truck 4, (ML) &Truck 5, (IL)	1.6	0.0	1.6
	Truck 6, (O.L)& Truck 1, (M.L) &Truck 2, (I.L)	1.5	0.0	1.5
M_34	Multiple presence	1.7	0.0	1.7

Table 5.6 – Summary of peak stresses (ksi) measured in strain gage CH_12 installed on the east tie plate of Floorbeam 8 in Span 34 approximately 4 in west to the east girder centerline and 1 in from the edge of the tie plate as the test trucks crossed in the northbound direction over the span in the crawl tests

Span 35, east tie plate of Floorbeam 2							
Test name	Truck in lane	CH_39, (ksi)			CH_40, (ksi)		
		σ_{max}	σ_{min}	$\Delta\sigma$	σ_{max}	σ_{min}	$\Delta\sigma$
CRL1_34	Truck 1, (O.L)	0.3	-0.6	0.9	1.1	0.0	1.1
	Truck 2, (O.L)	0.4	-0.6	1.0	1.1	0.0	1.1
	Truck 3, (M.L)	0.1	-0.5	0.6	0.6	0.0	0.6
	Truck 4, (M.L)	0.1	-0.5	0.6	0.6	0.0	0.6
	Truck 5, (I.L)	0.1	-0.5	0.6	0.6	0.0	0.6
	Truck 6, (I.L)	0.1	-0.5	0.6	0.6	0.0	0.6
CRL2_34	Truck 1, (O.L)& Truck 2, (M.L)	0.4	-1.1	1.5	1.5	0.0	1.5
	Truck 3, (OL)& Truck 4, (ML)	0.3	-1.0	1.3	1.3	0.0	1.3
CRL3_34	Truck 5, (M.L)& Truck 6, (I.L)	0.3	-1.0	1.3	1.0	0.0	1.0
	Truck 1, (ML)& Truck 2, (IL)	0.2	-1.0	1.2	1.0	0.0	1.0
CRL4_34	Truck 3, (OL)& Truck 4, (ML) &Truck 5, (IL)	0.5	-1.6	2.1	1.7	0.0	1.7
	Truck 6, (O.L)& Truck 1, (M.L) &Truck 2, (I.L)	0.5	-1.6	2.1	1.9	0.0	1.9
M_34	Multiple presence	0.6	-1.8	2.4	1.9	0.0	1.9

Table 5.7 – Summary of peak stresses (ksi) measured in strain gages CH_39 and CH_40 installed on the east tie plate of Floorbeam 2 in Span 35 approximately 4 in west to the centerline of the east girder and 1 in from the edge of the tie plate as the test trucks crossed in the northbound direction over the span in the crawl tests

Span 36, east tie plate of Floorbeam 8							
Test name	Truck in lane	CH_16, (ksi)			CH_17, (ksi)		
		σ_{max}	σ_{min}	$\Delta\sigma$	σ_{max}	σ_{min}	$\Delta\sigma$
CRL1_36	Truck 1, (O.L)	1.1	0.0	1.1	0.8	0.0	0.8
	Truck 2, (O.L)	1.1	0.0	1.1	0.7	0.0	0.7
	Truck 3, (M.L)	0.4	0.0	0.4	0.3	0.0	0.3
	Truck 4, (M.L)	0.5	0.0	0.5	0.7	0.0	0.7
	Truck 5, (I.L)	0.6	0.0	0.6	0.7	0.0	0.7
	Truck 6, (I.L)	0.6	0.0	0.6	0.7	0.0	0.7
CRL2_36	Truck 1, (O.L)& Truck 2, (M.L)	1.2	-0.1	1.3	0.9	-0.1	1.0
	Truck 3, (OL)& Truck 4, (ML)	1.3	-0.1	1.4	0.9	-0.1	1.0
CRL3_36	Truck 5, (M.L)& Truck 6, (I.L)	0.8	0.0	0.8	1.0	-0.3	1.3
	Truck 1, (ML)& Truck 2, (IL)	0.8	0.0	0.8	0.8	-0.3	1.1
CRL4_36	Truck 3, (OL)& Truck 4, (ML) &Truck 5, (IL)	1.6	0.0	1.6	1.4	-0.3	1.7
	Truck 6, (O.L)& Truck 1, (M.L) &Truck 2, (I.L)	1.9	0.0	1.9	1.4	-0.3	1.7
M_36	Multiple presence	2.1	0.0	2.1	1.8	-0.3	2.1

Table 5.8 – Summary of peak stresses (ksi) measured in strain gages CH_16 and CH_17 installed on the east tie plate of Floorbeam 8 at the centerline of the east girder and 1 in from the edge of the tie plate as the test trucks crossed in the northbound direction over the span in the crawl tests

Span 38, east tie plate of Floorbeam 2							
Test name	Truck in lane	CH_45, (ksi)			CH_46, (ksi)		
		σ_{max}	σ_{min}	$\Delta\sigma$	σ_{max}	σ_{min}	$\Delta\sigma$
CRL1_36	Truck 1, (O.L)	0.8	-0.9	1.7	1.5	0.0	1.5
	Truck 2, (O.L)	0.8	-0.8	1.6	1.5	0.0	1.5
	Truck 3, (M.L)	0.1	-0.7	0.8	0.6	0.0	0.6
	Truck 4, (M.L)	0.1	-0.7	0.8	0.6	0.0	0.6
	Truck 5, (I.L)	0.2	-0.7	0.9	0.8	0.0	0.8
	Truck 6, (I.L)	0.2	-0.7	0.9	0.8	0.0	0.8
CRL2_36	Truck 1, (O.L)& Truck 2, (M.L)	0.8	-1.5	2.3	2.1	-0.2	2.3
	Truck 3, (OL)& Truck 4, (ML)	0.9	-1.5	2.4	2.0	-0.3	2.3
CRL3_36	Truck 5, (M.L)& Truck 6, (I.L)	0.2	-1.4	1.6	1.4	0.0	1.4
	Truck 1, (ML)& Truck 2, (IL)	0.0	-1.0	1.0	0.9	0.0	0.9
CRL4_36	Truck 3, (OL)& Truck 4, (ML) &Truck 5, (IL)	1.0	-1.9	2.9	2.7	0.0	2.7
	Truck 6, (O.L)& Truck 1, (M.L) &Truck 2, (I.L)	1.0	-1.9	2.9	2.7	0.0	2.7
M_36 (raw)	Multiple presence	2.0	-1.7	3.7	0.8	-2.4	3.2
M_36 (modified)	Multiple presence	1.5	-2.2	3.7	3.2	0.0	3.2

Table 5.9 – Summary of peak stresses (ksi) measured in strain gages CH_45 and CH_46 installed on the east tie plate of Floorbeam 2 in Span 38 approximately 4 in west to the centerline of the east girder and 1 in from the edge of the tie plate as the test trucks crossed in the northbound direction over the span in the crawl tests

Span 45, east tie plate of Floorbeam 2							
Test name	Truck in lane	CH_12, (ksi)			CH_13, (ksi)		
		σ_{max}	σ_{min}	$\Delta\sigma$	σ_{max}	σ_{min}	$\Delta\sigma$
CRL1_45	Truck 1, (O.L)	0.9	-0.2	1.1	1.1	0.0	1.1
	Truck 2, (O.L)	0.9	-0.2	1.1	1.1	0.0	1.1
	Truck 3, (M.L)	0.2	-0.2	0.4	0.5	0.0	0.5
	Truck 4, (M.L)	0.2	-0.2	0.4	0.4	0.0	0.4
	Truck 5, (I.L)	0.4	-0.2	0.6	0.6	0.0	0.6
	Truck 6, (I.L)	0.4	-0.2	0.6	0.5	0.0	0.5
CRL2_45	Truck 1, (O.L)& Truck 2, (M.L)	1.2	-0.5	1.7	1.5	0.0	1.5
	Truck 3, (OL)& Truck 4, (ML)	0.9	-0.5	1.4	1.5	0.0	1.5
CRL3_45	Truck 5, (M.L)& Truck 6, (I.L)	0.5	-0.6	1.1	1.0	0.0	1.0
	Truck 1, (ML)& Truck 2, (IL)	0.6	-0.5	1.1	1.0	0.0	1.0
[1]CRL4_45	Truck 3, (OL)& Truck 4, (ML) &Truck 5, (IL)	NA	NA	NA	NA	NA	NA
	Truck 6, (O.L)& Truck 1, (M.L) &Truck 2, (I.L)	NA	NA	NA	NA	NA	NA
M_45	Multiple presence	1.3	-0.7	2.0	1.9	-0.1	2.0

Note:
1. Data for this test were not retrieved

Table 5.10 – Summary of peak stresses (ksi) measured in strain gages CH_12 and CH_13 installed on the east tie plate of Floorbeam 2 in Span 45 approximately 4 in west to the centerline of the east girder and 1 in from the edge of the tie plate as the test trucks crossed in the northbound direction over the span in the crawl tests

5.3.3 Stresses in the Web of Non-retrofitted Floorbeam of Span 38

Cracks have been discovered on the web of various floorbeams where the top lateral bracing system frames into the floorbeam web. Strain gage CH_44 was installed on the web of Floorbeam 2 in Span 38 (the control span) to assess the magnitude of the stress range experienced by the detail and to serve as a baseline for comparison between the response of the non-retrofitted floorbeam web of Span 38 and those where prototype retrofits have been installed in Span 35, 36, and 45.

The response of the strain gage as Truck 2 crossed in the northbound direction over Span 38 in the outside lane in the crawl test CRL1_36 is shown in Figure 5.4. A summary of the maximum stress, minimum stress, and stress range values experienced by the gages in the crawl tests, including the multiple presence truck test is presented in Table 5.11. It is important to note that this detail can be classified as Category B detail per AASHTO Specifications. The maximum stress range measured during the crawl controlled load tests is 1.3 ksi, which is considerably below the CAFL of the detail (16 ksi). The low measured stresses could be a result of not placing the gage at the critical location on the web.

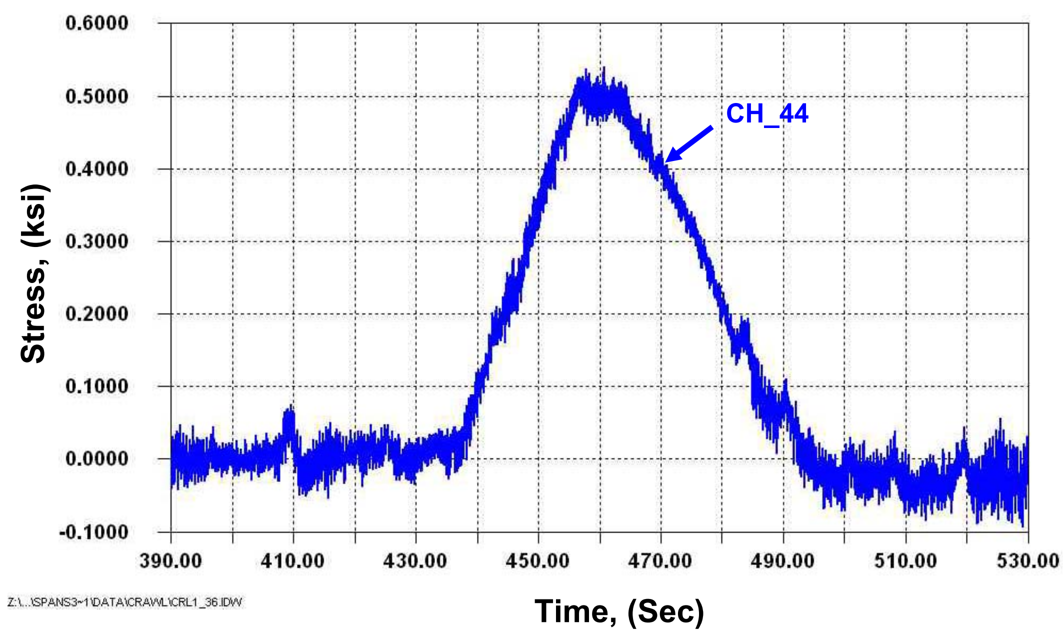


Figure 5.4 – Response of strain gage CH_44 installed non-retrofitted web of Floorbeam 2 at the floorbeam/east girder intersection and at a distance of approximately 21 1/2" west of the centerline of the east girder and approximately 5 1/2" below the bottom face of the floorbeam top flange in Span 35 (south face of floorbeam web) as Truck 2 crossed in the northbound direction in the outside lane in the crawl test CRL1_36.

Span 38, WT non-retrofitted floorbeam web				
Test name	Truck in lane	CH_44, (ksi)		
		σ_{max}	σ_{min}	$\Delta\sigma$
CRL1_36	Truck 1, (O.L)	0.5	-0.1	0.6
	Truck 2, (O.L)	0.5	-0.1	0.6
	Truck 3, (M.L)	0.4	-0.1	0.5
	Truck 4, (M.L)	0.4	-0.1	0.5
	Truck 5, (I.L)	0.3	-0.1	0.4
	Truck 6, (I.L)	0.3	-0.1	0.4
CRL2_36	Truck 1, (O.L)& Truck 2, (M.L)	1.0	-0.2	1.2
	Truck 3, (OL)& Truck 4, (ML)	1.0	-0.2	1.2
CRL3_36	Truck 5, (M.L)& Truck 6, (I.L)	0.8	-0.1	0.9
	Truck 1, (ML)& Truck 2, (IL)	0.6	-0.1	0.7
CRL4_36	Truck 3, (OL)& Truck 4, (ML) &Truck 5, (IL)	1.1	-0.1	1.2
	Truck 6, (O.L)& Truck 1, (M.L) &Truck 2, (I.L)	1.2	-0.1	1.3
M_36 (raw)	Multiple presence	0.4	-0.9	1.3
M_36 (modified)	Multiple presence	1.3	0.0	1.3

Table 5.11 – Summary of peak stresses (ksi) measured in strain gage CH_44 installed on the non-retrofitted web of Floorbeam 2 at the floorbeam/east girder intersection and at a distance of approximately 21 1/2" west of the centerline of the east girder and approximately 5 1/2" below the bottom face of the floorbeam top flange in Span 38 (north face of floorbeam web) as the test trucks crossed in the northbound direction over the span in the crawl tests

5.3.4 Stresses in the WT-Section Bolted to Floorbeam Web

As previously noted, WT-sections were bolted to the web of selected floorbeams to increase the cross sectional area of the web and reduce the out-of-plane stresses induced on the web by the lateral bracing system. Strain gages CH_41, CH_18, and CH_15 were installed on the WT of Floorbeam 2 in Span 35 (south face of floorbeam web), the WT of Floorbeam 8 in Span 36 (north face of floorbeam web), and the WT of Floorbeam 2 in Span 45 (north face of floorbeam web), respectively. The gages were installed on the WT's bolted to the web of the floorbeams at the floorbeam/east girder intersection and at a distance of approximately 21 1/2 in west of the centerline of the east girder and approximately 5 1/2 in below the bottom face of the floorbeam top flange.

This detail is classified as Category B detail per AASHTO Specifications with constant amplitude fatigue limit (CAFL) of 16 ksi. Figure 5.5 presents the response of CH_41 installed on the WT of Floorbeam 2 at the floorbeam/east girder intersection and at a distance of approximately 21 1/2 in west of the centerline of the east girder and approximately 5 1/2 in below the bottom face of the floorbeam top flange in Span 35 (south face of floorbeam web) as Truck 2 crossed over the outside lane in the northbound direction in the crawl test CRL1_36. The reversed sign in the response of strain gages CH_18 and CH_15 when compared to strain gage CH_41 is due to CH_41 being installed on the south face of the web of Floorbeam 2, which is opposite to strain gages CH_18 and CH_15 which were installed on the north face of the web of Floorbeam 8 and Floorbeam 2, respectively. Summaries of the maximum stress, minimum stress, and stress range values experienced by the gages in the crawl tests, including the multiple presence truck test are presented in Tables 5.12 through 5.14.

The prototype retrofit of the web of Floorbeam 8 in Span 36 is similar to that of Floorbeam 2 in Span 45, the tables show that similar magnitude of stress range was recorded by strain gage CH_15 installed on the WT connected to the web of Floorbeam 2 in Span 45 and strain gage CH_18 installed on the WT connected to the web of Floorbeam 8 in Span 36. The tables also show that stresses measured by strain gage CH_41 installed on the WT bolted to the web of Floorbeam 2 in Span 35 is almost twice as high than that of strain gage CH_15 or strain gage CH_18, indicating that the prototype floorbeam web retrofit installed in Span 36 and Span 45 or a combination of the shear connectors and the floorbeam web retrofit installed in same spans is more effective in reducing the out-of-plane bending stresses than the prototype floorbeam retrofit installed in Span 35. It is important to note that although the stresses measured during the controlled load tests by gage CH_41 are approximately twice that measured by strain gages CH_15 and CH_18, the magnitude of stresses measured by all gages are considerably less than the CAFL of the detail.

It is important to note that the response of strain gage CH_41 installed on the WT of Floorbeam 2 in Span 35 is 33.3% to 66.6% less than the response of CH_44 installed on the non-retrofitted web of Floorbeam 2 in Span 38. This is an indication of significant reduction in the out-of-plane stresses resulting from the existence of the prototype floorbeam retrofit, which was the only prototype retrofit installed in Span 35 (i.e., no shear connectors or new sub-floorbeams). Similar comparison indicates 66.6% to 80% reduction in the response of CH_41 installed on the WT of Floorbeam 2 in Span 35 when compared response of CH_44 installed on the non-retrofitted web of Floorbeam 2 in Span 38, indicating also significant reduction in the out-of-plane stresses resulting from the existence of the prototype floorbeam retrofits as well as the shear connectors.

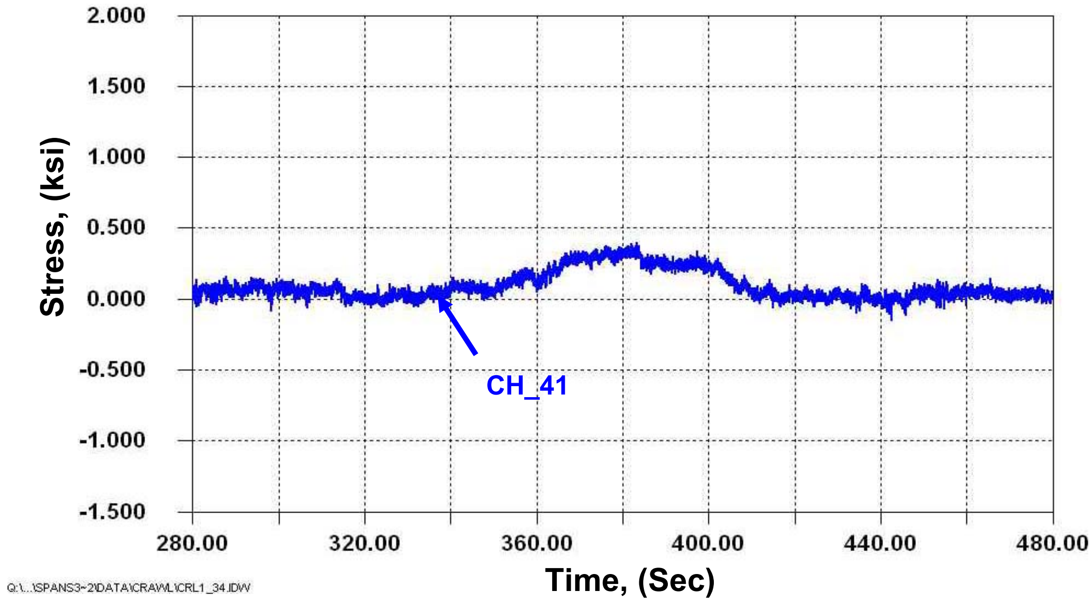


Figure 5.5 – Response of strain gage CH_41 installed on the WT of Floorbeam 2 at the floorbeam/east girder intersection and at a distance of approximately 21 1/2" west of the centerline of the east girder and approximately 5 1/2" below the bottom face of the floorbeam top flange in Span 35 (south face of floorbeam web) as Truck 2 crossed in the northbound direction in the outside lane in the crawl test CRL1_36

Span 35, WT at east girder-to-Floorbeam 2 connection				
Test name	Truck in lane	CH_41, (ksi)		
		σ_{max}	σ_{min}	$\Delta\sigma$
CRL1_34	Truck 1, (O.L)	0.4	0.0	0.4
	Truck 2, (O.L)	0.4	0.0	0.4
	Truck 3, (M.L)	0.2	0.0	0.2
	Truck 4, (M.L)	0.2	0.0	0.2
	Truck 5, (I.L)	0.2	0.0	0.2
	Truck 6, (I.L)	0.2	0.0	0.2
CRL2_34	Truck 1, (O.L)& Truck 2, (M.L)	0.6	0.0	0.6
	Truck 3, (OL)& Truck 4, (ML)	0.4	0.0	0.4
CRL3_34	Truck 5, (M.L)& Truck 6, (I.L)	0.5	0.0	0.5
	Truck 1, (ML)& Truck 2, (IL)	0.4	0.0	0.4
CRL4_34	Truck 3, (OL)& Truck 4, (ML) &Truck 5, (IL)	0.7	0.0	0.7
	Truck 6, (O.L)& Truck 1, (M.L) &Truck 2, (I.L)	0.6	0.0	0.6
M_34	Multiple presence	0.6	0.0	0.6

Table 5.12 – Summary of peak stresses (ksi) measured in strain gage CH_41 installed on the WT of Floorbeam 2 at the floorbeam/east girder intersection and at a distance of approximately 21 1/2" west of the centerline of the east girder and approximately 5 1/2" below the bottom face of the floorbeam top flange in Span 35 (south face of floorbeam web) as the test trucks crossed in the northbound direction over the span in the crawl tests

Span 36, WT at east girder-to-Floorbeam 8 connection				
Test name	Truck in lane	CH_18, (ksi)		
		σ_{max}	σ_{min}	$\Delta\sigma$
CRL1_36	Truck 1, (O.L)	0.0	-0.2	0.2
	Truck 2, (O.L)	0.0	-0.2	0.2
	Truck 3, (M.L)	0.0	-0.1	0.1
	Truck 4, (M.L)	0.0	-0.1	0.1
	Truck 5, (I.L)	0.0	-0.1	0.1
	Truck 6, (I.L)	0.0	-0.1	0.1
CRL2_36	Truck 1, (O.L)& Truck 2, (M.L)	0.0	-0.3	0.3
	Truck 3, (OL)& Truck 4, (ML)	0.0	-0.3	0.3
CRL3_36	Truck 5, (M.L)& Truck 6, (I.L)	0.0	-0.2	0.2
	Truck 1, (ML)& Truck 2, (IL)	0.0	-0.2	0.2
CRL4_36	Truck 3, (OL)& Truck 4, (ML) &Truck 5, (IL)	0.0	-0.3	0.3
	Truck 6, (O.L)& Truck 1, (M.L) &Truck 2, (I.L)	0.0	-0.3	0.3
M_36	Multiple presence	0.0	-0.3	0.3

Table 5.13 – Summary of peak stresses (ksi) measured in strain gage CH_18 installed on the WT of Floorbeam 8 bolted to the web of the floorbeam at the floorbeam/east girder intersection and at a distance of approximately 21 1/2" west of the centerline of the east girder and approximately 5 1/2" below the bottom face of the floorbeam top flange in Span 36 (north face of floorbeam web) as the test trucks crossed in the northbound direction over the span in the crawl tests

Span 45, WT at east girder-to-Floorbeam 2 connection				
Test name	**Truck in lane**	**CH_15, (ksi)**		
		σ_{max}	σ_{min}	$\Delta\sigma$
CRL1_45	**Truck 1, (O.L)**	0.0	-0.2	0.2
	Truck 2, (O.L)	0.0	-0.2	0.2
	Truck 3, (M.L)	0.0	-0.2	0.2
	Truck 4, (M.L)	0.0	-0.2	0.2
	Truck 5, (I.L)	0.0	-0.1	0.1
	Truck 6, (I.L)	0.0	-0.1	0.1
CRL2_45	**Truck 1, (O.L)& Truck 2, (M.L)**	0.1	-0.2	0.3
	Truck 3, (OL)& Truck 4, (ML)	0.1	-0.2	0.3
CRL3_45	**Truck 5, (M.L)& Truck 6, (I.L)**	0.1	-0.2	0.3
	Truck 1, (ML)& Truck 2, (IL)	0.1	-0.2	0.3
[1]CRL4_45	**Truck 3, (OL)& Truck 4, (ML) &Truck 5, (IL)**	NA	NA	NA
	Truck 6, (O.L)& Truck 1, (M.L) &Truck 2, (I.L)	NA	NA	NA
M_45	**Multiple presence**	0.0	-0.2	0.2

Note:
1. Data for this test were not retrieved

Table 5.14 – Summary of peak stresses (ksi) measured in strain gage CH_15 installed on the WT of Floorbeam 2 bolted to the web of the floorbeam at the floorbeam/east girder intersection and at a distance of approximately 21 1/2" west of the centerline of the east girder and approximately 5 1/2" below the bottom face of the floorbeam top flange in Span 36 (north face of floorbeam web) as the test trucks crossed in the northbound direction over the span in the crawl tests

5.3.5 Stresses in the Web of Prototype Shear Connectors at Cutout Detail

As previously discussed, prototype longitudinal shear connectors were installed in Span 34, Span 36, and Span 45 at the north and south end of each span between the top flange of the main girders (east girder and west girder) and the bottom face of the steel deck plate such that positive attachment between the main girders and the deck plate could be established. The response of the shear connectors to moving load was investigated by installing strain gages on the web plate of the east shear connector at various fatigue prone details including the cutout details of the connector web plates in Span 34 and Span 45. The gages were installed back-to-back on the web at the cutouts to measure any out-of-plane bending in the web plates.

In Span 34, strain gages CH_23 and CH_24 were installed back-to-back on the web plate at the south cutout detail of the east shear connector located at the north end of the span. The gages were installed back-to-back on the plate at a perpendicular distance of 1/4 in from the cutout and at a vertical distance of approximately 27 in from the top face of the top flange. Strain gages CH_25 and CH_26 were installed back-to-back on the same plate at a perpendicular distance of 1/4 in from the cut and at a vertical distance of approximately 20 1/2 in from the top face of the top flange.

In Span 45, Strain gages CH_33 and CH_34 were installed back-to-back on the web plate of the east shear connector located at the north end of the span. The gages were installed on the south cutout detail of the east shear connector at a perpendicular distance of 1/4 in from the cut and at a vertical distance of approximately 27 in from the top face of the top flange. In the same span, strain gage CH_35 and CH_36 were installed at location similar to where strain gages CH_25 and CH_26 were installed in Span 34.

This detail is classified as Category A detail per AASHTO Specifications with constant amplitude fatigue limit (CAFL) of 24 ksi. The maximum stress range was measured by stress range CH_34 during the crawl tests and was recorded to be 7.9 ksi, which is well below the CAFL of the detail.

Figure 5.6 presents the response of strain gages CH_23 and CH_24 installed back-to-back on the web plate at the south cutout detail of the east shear connector located at the north end of Span 34 as Truck 1 crossed over the span in the outside lane during the controlled load test CRL1_34. The figure shows that response in both gages was identical, suggesting no out-of-plane bending behavior of the web plate of the shear connector at the instrumented location.

In Figure 5.7, the response of strain gage CH_25 and CH_26 installed back-to-back on the same cutout slightly below gages CH_23 and CH_24, as Truck 1 crossed over the span in the outside lane during the controlled load test CRL1_34, indicates slight localized response, suggesting that shear connector web plate experience small localized out-of-plane bending stresses along with the in-plane stresses at the instrumented location.

The localized response in the shear connector can be seen clearly in Figure 5.8, which shows the time history response of strain gages CH_33, CH_34, CH_35, and CH_36 as Truck 1 and Truck 2 traveled side-by-side in the outside and middle lane, respectively. The presence of the Truck 2 in the middle lane appears to have a major effect on the response of the detail. Summaries of the maximum stress, minimum stress, and stress range values experienced by the gages in the crawl tests, including the multiple presence truck test are listed in Tables 5.15 through 5.18.

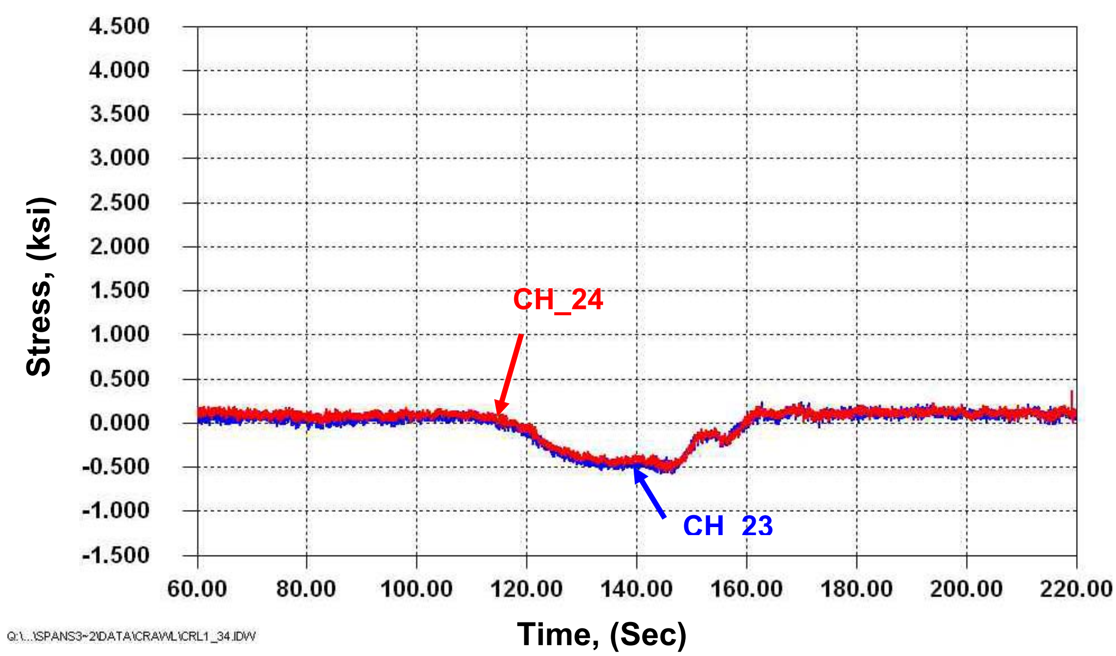


Figure 5.6 – Response of strain gage CH_23 and CH_24 installed back-to-back on the web plate at the south cutout detail (at a vertical distance of approximately 27 in from the top face of the top flange, and 1/4" from the cut edge) of the east shear connector located at the north end of Span 34 as Truck 1 crossed in the northbound direction over the span in the outside lane in the controlled load test CRL1_34

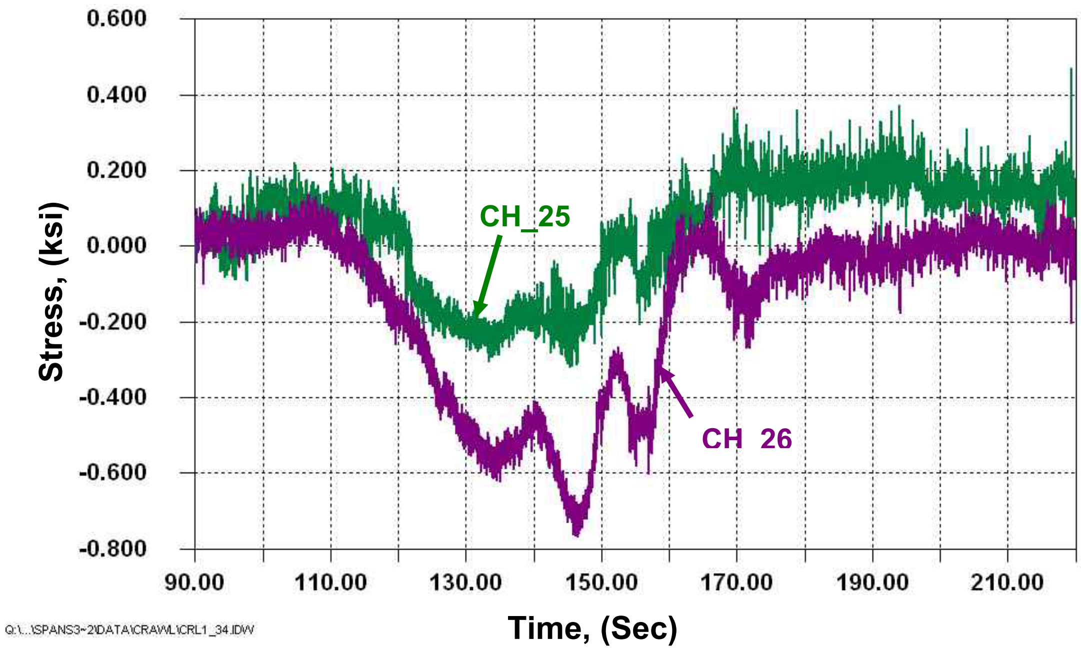


Figure 5.7 – Response of strain gage CH_25 and CH_26 installed back-to-back on the web plate at the south cutout detail (below strain gage CH_23 and CH_24, at a vertical distance of approximately 20 1/2" from the top face of the top flange, and 1/4" from the cut edge) of the east shear connector located at the north end of the span as Truck 1 crossed in the northbound direction over Span 34 in the outside lane in the controlled load test CRL1_34

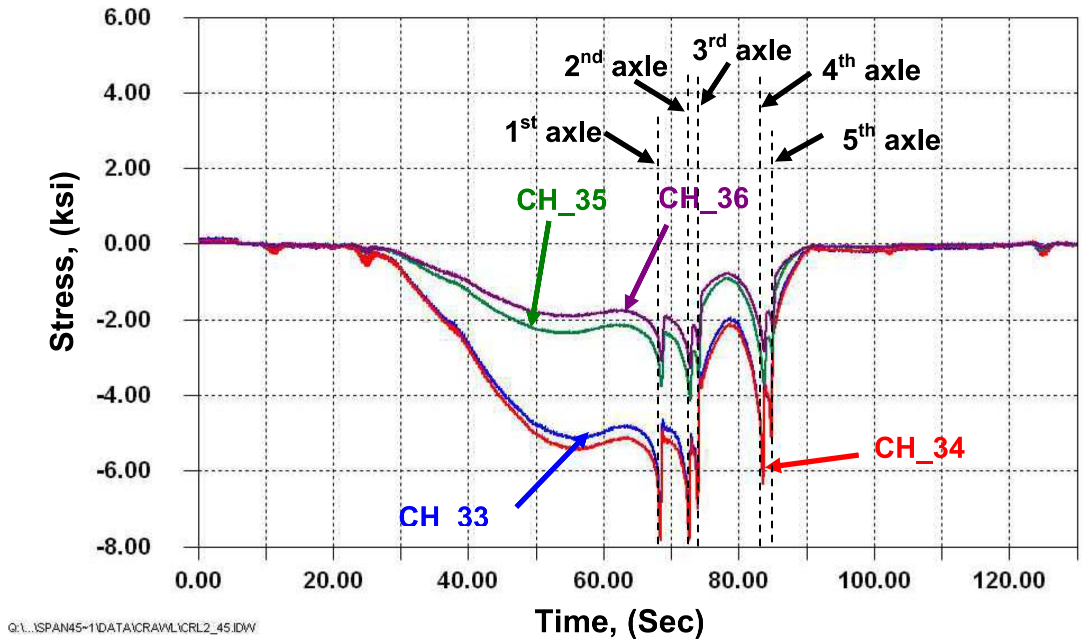


Figure 5.8 – Response of strain gages CH_33, CH_34, CH_35, and CH_36 installed on the web plate at the south cutout detail on the east shear connector located at the north end of Span 45 as Truck 1 and Truck 2 crossed side-by-side in the northbound direction over the span in the outside and middle lane during the controlled load test CRL2_45

Span 34, south cutout detail on east shear connector at north end of the span							
Test name	**Truck in lane**	**CH_23, (ksi)**			**CH_24, (ksi)**		
		σ_{max}	σ_{min}	$\Delta\sigma$	σ_{max}	σ_{min}	$\Delta\sigma$
CRL1_34	**Truck 1, (O.L)**	0.1	-0.6	0.7	0.1	-0.6	0.7
	Truck 2, (O.L)	0.1	-0.5	0.6	0.1	-0.5	0.6
	Truck 3, (M.L)	0.1	-0.6	0.7	0.1	-0.6	0.7
	Truck 4, (M.L)	0.1	-0.7	0.8	0.1	-0.7	0.8
	Truck 5, (I.L)	0.1	-0.4	0.5	0.1	-0.4	0.5
	Truck 6, (I.L)	0.1	-0.4	0.5	0.1	-0.4	0.5
CRL2_34	**Truck 1, (O.L)& Truck 2, (M.L)**	0.0	-1.5	1.5	0.0	-1.5	1.5
	Truck 3, (OL)& Truck 4, (ML)	0.1	-1.2	1.3	0.1	-1.2	1.3
CRL3_34	**Truck 5, (M.L)& Truck 6, (I.L)**	0.1	-1.3	1.4	0.1	-1.2	1.3
	Truck 1, (ML)& Truck 2, (IL)	0.1	-1.2	1.3	0.1	-1.2	1.3
CRL4_34	**Truck 3, (OL)& Truck 4, (ML) &Truck 5, (IL)**	0.0	-0.5	0.5	0.0	-0.5	0.5
	Truck 6, (O.L)& Truck 1, (M.L) &Truck 2, (I.L)	0.0	-0.5	0.5	0.0	-0.5	0.5
M_34	**Multiple presence**	0.1	-1.5	1.6	0.1	-1.5	1.6

Table 5.15 – Summary of peak stresses (ksi) measured in strain gages CH_23 and CH_24 installed back-to-back on the web plate at the south cutout detail (at a vertical distance of approximately 27in from the top face of the top flange) of the east shear connector located at the north end of Span 34 as the test trucks crossed in the northbound direction over the span in the crawl tests

Span 34, south cutout detail on east shear connector at north end of the span							
Test name	Truck in lane	CH_25, (ksi)			CH_26, (ksi)		
		σ_{max}	σ_{min}	$\Delta\sigma$	σ_{max}	σ_{min}	$\Delta\sigma$
CRL1_34	Truck 1, (O.L)	0.1	-0.3	0.4	0.1	-0.8	0.9
	Truck 2, (O.L)	0.1	-0.3	0.4	0.1	-0.7	0.8
	Truck 3, (M.L)	0.1	-0.4	0.5	0.0	-1.5	1.5
	Truck 4, (M.L)	0.1	-0.4	0.5	0.0	-1.3	1.3
	Truck 5, (I.L)	0.0	-0.2	0.2	0.0	-0.4	0.4
	Truck 6, (I.L)	0.0	-0.2	0.2	0.0	-0.4	0.4
CRL2_34	Truck 1, (O.L)& Truck 2, (M.L)	0.3	-0.7	1.0	0.0	-2.5	2.5
	Truck 3, (OL)& Truck 4, (ML)	0.2	-0.7	0.9	0.1	-1.9	1.9
CRL3_34	Truck 5, (M.L)& Truck 6, (I.L)	0.1	-1.0	1.1	0.0	-1.8	1.8
	Truck 1, (ML)& Truck 2, (IL)	0.0	-0.9	0.9	0.0	-2.0	2.0
CRL4_34	Truck 3, (OL)& Truck 4, (ML) &Truck 5, (IL)	0.0	-0.5	0.5	0.0	-2.2	2.2
	Truck 6, (O.L)& Truck 1, (M.L) &Truck 2, (I.L)	0.0	-0.6	0.6	0.0	-2.6	2.6
M_34	Multiple presence	0.4	-0.8	1.2	0.0	-2.1	2.1

Table 5.16 – Summary of peak stresses (ksi) measured in strain gages CH_25 and CH_26 installed back-to-back on the web plate at the south cutout detail (at a vertical distance of approximately 20 1/2" from the top face of the top flange) of the east shear connector located at the north end of Span 34 as the test trucks crossed in the northbound direction over the span in the crawl tests

Span 45, south cutout detail on east shear connector at north end of the span							
Test name	Truck in lane	CH_33, (ksi)			CH_34, (ksi)		
		σ_{max}	σ_{min}	$\Delta\sigma$	σ_{max}	σ_{min}	$\Delta\sigma$
CRL1_45	Truck 1, (O.L)	0.0	-3.0	3.0	0.0	-3.2	3.2
	Truck 2, (O.L)	0.0	-3.0	3.0	0.0	-3.2	3.2
	Truck 3, (M.L)	0.0	-5.6	5.6	0.0	-5.8	5.8
	Truck 4, (M.L)	0.0	-4.7	4.7	0.0	-5.1	5.1
	Truck 5, (I.L)	0.0	-1.7	1.7	0.0	-1.7	1.7
	Truck 6, (I.L)	0.0	-1.7	1.7	0.0	-1.9	1.9
CRL2_45	Truck 1, (O.L)& Truck 2, (M.L)	0.0	-7.3	7.3	0.0	-7.9	7.9
	Truck 3, (OL)& Truck 4, (ML)	0.0	-6.8	6.8	0.0	-7.4	7.4
CRL3_45	Truck 5, (M.L)& Truck 6, (I.L)	0.0	-5.9	5.9	0.0	-6.1	6.1
	Truck 1, (ML)& Truck 2, (IL)	0.0	-5.1	5.1	0.0	-5.7	5.7
[1]CRL4_45	Truck 3, (OL)& Truck 4, (ML) &Truck 5, (IL)	NA	NA	NA	NA	NA	NA
	Truck 6, (O.L)& Truck 1, (M.L) &Truck 2, (I.L)	NA	NA	NA	NA	NA	NA
M_45	Multiple presence	0.0	-6.8	6.8	0.0	-7.3	7.3

Note:
1. Data for this test were not retrieved

Table 5.17 – Summary of peak stresses (ksi) measured in strain gages CH_33 and CH_34 installed back-to-back on the web plate at the south cutout detail (at a vertical distance of approximately 27in from the top face of the top flange) of the east shear connector located at the north end of Span 45 as the test trucks crossed in the northbound direction over the span in the crawl tests

Span 45, south cutout detail on east shear connector at north end of the span							
Test name	Truck in lane	CH_35, (ksi)			CH_36, (ksi)		
		σ_{max}	σ_{min}	$\Delta\sigma$	σ_{max}	σ_{min}	$\Delta\sigma$
CRL1_45	Truck 1, (O.L)	0.0	-1.4	1.4	0.0	-1.1	1.1
	Truck 2, (O.L)	0.0	-1.4	1.4	0.0	-1.2	1.2
	Truck 3, (M.L)	0.0	-3.1	3.1	0.0	-2.5	2.5
	Truck 4, (M.L)	0.0	-3.0	3.0	0.0	-2.3	2.3
	Truck 5, (I.L)	0.0	-0.8	0.8	0.0	-0.6	0.6
	Truck 6, (I.L)	0.0	-0.8	0.8	0.0	-0.7	0.7
CRL2_45	Truck 1, (O.L)& Truck 2, (M.L)	0.0	-4.1	4.1	0.0	-3.2	3.2
	Truck 3, (OL)& Truck 4, (ML)	0.0	-3.8	3.8	0.0	-3.1	3.1
CRL3_45	Truck 5, (M.L)& Truck 6, (I.L)	0.0	-3.5	3.5	0.0	-2.6	2.6
	Truck 1, (ML)& Truck 2, (IL)	0.0	-3.3	3.3	0.0	-2.5	2.5
[1]CRL4_45	Truck 3, (OL)& Truck 4, (ML) &Truck 5, (IL)	NA	NA	NA	NA	NA	NA
	Truck 6, (O.L)& Truck 1, (M.L) &Truck 2, (I.L)	NA	NA	NA	NA	NA	NA
M_45	Multiple presence	0.0	-3.6	3.6	0.0	-2.8	2.8

Note:
1. Data for this test were not retrieved

Table 5.18 – Summary of peak stresses (ksi) measured in strain gages CH_35 and CH_36 installed back-to-back on the web plate at the south cutout detail (at a vertical distance of approximately 20 1/2" from the top face of the top flange) of the east shear connector located at the north end of Span 45 as the test trucks crossed in the northbound direction over the span in the crawl tests

5.3.6 Stresses in the Web of Prototype Shear Connectors near Welded Detail

As previously discussed, strain gage CH_39 was installed on the web plate of the east shear connector located at the north end of Span 45. The gage was installed near the north end of the plate and longitudinally along the longitudinal weld used for attaching the shear connector to the bottom face of the deck steel plate in Span 45. The response of the strain gage to the crossing of Truck 1 in the outside lane over the span in the northbound direction in the controlled load test CRL1_45 is shown in Figure 5.9. The figure shows low response measured by the strain gage during the crossing of Truck 1 in the outside lane. The response of the strain gage to the passage of the test truck(s) in all crawl tests was low as indicated in Table 5.19.

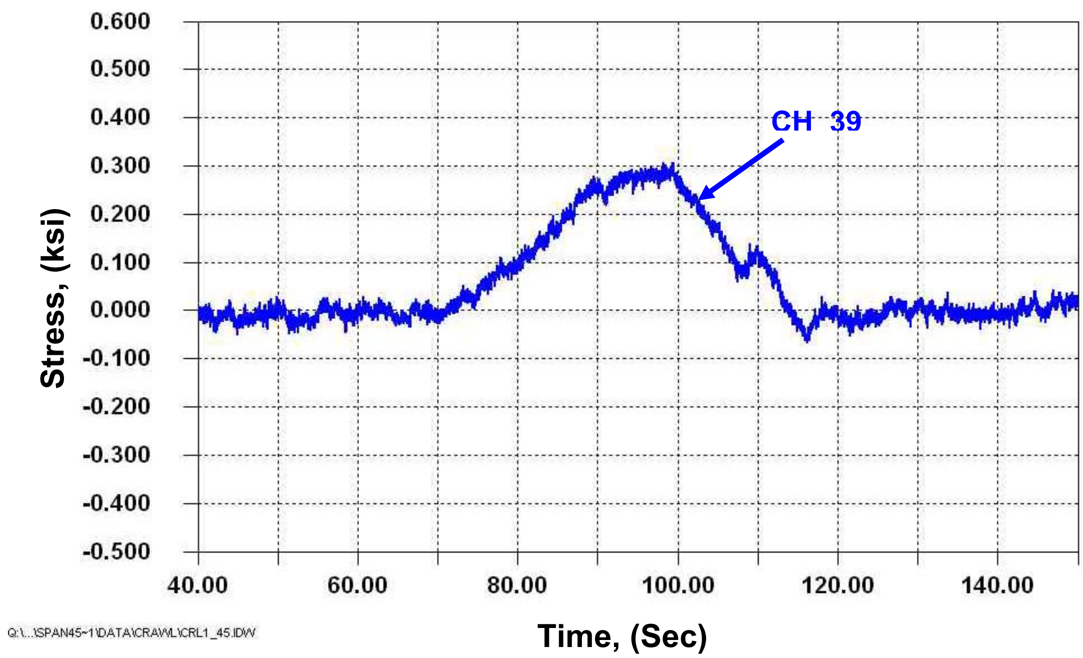


Figure 5.9 – Response of strain gage CH_39 installed on the web plate of the east shear connector located at the north end of Span 45 near the north end of the plate and longitudinally along the longitudinal weld used for attaching the shear connector to the bottom face of the deck steel plate in Span 45 as Truck 1 crossed in the northbound direction over the span in the outside lane during the controlled load test CRL1_45.

Span 45, east shear connector web at north end of the span and along weld line				
Test name	Truck in lane	CH_39, (ksi)		
		σ_{max}	σ_{min}	$\Delta\sigma$
CRL1_45	Truck 1, (O.L)	0.3	0.0	0.3
	Truck 2, (O.L)	0.3	0.0	0.3
	Truck 3, (M.L)	0.2	0.0	0.2
	Truck 4, (M.L)	0.2	0.0	0.2
	Truck 5, (I.L)	0.2	0.0	0.2
	Truck 6, (I.L)	0.2	0.0	0.2
CRL2_45	Truck 1, (O.L)& Truck 2, (M.L)	0.6	0.0	0.6
	Truck 3, (OL)& Truck 4, (ML)	0.5	0.0	0.5
CRL3_45	Truck 5, (M.L)& Truck 6, (I.L)	0.4	0.0	0.4
	Truck 1, (ML)& Truck 2, (IL)	0.4	0.0	0.4
[1]CRL4_45	Truck 3, (OL)& Truck 4, (ML) &Truck 5, (IL)	NA	NA	NA
	Truck 6, (O.L)& Truck 1, (M.L) &Truck 2, (I.L)	NA	NA	NA
M_45	Multiple presence	0.0	0.7	0.7

Note:
1. Data for this test were not retrieved

Table 5.19 – Summary of peak stresses (ksi) measured in strain gage CH_39 installed on the web plate of the east shear connector located at the north end of Span 45 near the north end of the plate and longitudinally along the longitudinal weld used for attaching the shear connector to the bottom face of the deck steel plate in Span 45 as the test trucks crossed in the northbound direction over the span in the crawl tests

5.3.7 Stresses in the Web of Prototype Shear Connectors near Bolted Detail

As mentioned previously, in Span 36, strain gages CH_5, CH_6, and CH_7 were installed on the north shear connector (north end of the span) over the east girder and on the west face of the shear connector plate, where gage CH_5 was installed vertically on the web plate adjacent to the vertical stiffener angle, gage CH_6 was installed at 45 degree counter-clockwise from gage CH_5, and gage CH_7 was installed longitudinally along the longitudinal angle at 90 degree angle counter-clockwise from gage CH_5. Gages CH_8, CH_9, and CH_10 were installed directly behind gages CH_5, CH_6, and CH_7, respectively, on the east face of the shear connector web plate.

In a similar arrangement, strain gages CH_4, CH_5, and CH_6 were installed in Span 45 on the south shear connector (south end of the span) over the east girder and on the west face of the shear connector plate. Strain gage CH_4 was installed vertically on the web plate adjacent to the vertical stiffener angle, gage CH_5 was installed at 45 degree counter-clockwise from gage CH_4, and gage CH_6 was installed longitudinally along the longitudinal angle at 90 degree angle counter-clockwise from gage CH_5 as shown in Figure 4.7. Gages CH_7, CH_8, and CH_9 were installed directly behind gages CH_4, CH_5, and CH_6, respectively, on the east face of the shear connector web plate.

The response of strain gages CH_5, CH_6, and CH_7 during the passage of Truck 1 over Span 36 in the outside lane in the northbound direction in the controlled load test CRL1_36 is shown in Figure 5.10. As shown in the figure, low response was measured by the gages during the passage of the test truck. In fact, the response of all gages installed on the shear connector web plate near the bolted stiffener element is low as indicated in Table 5.20 through Table 5.23.

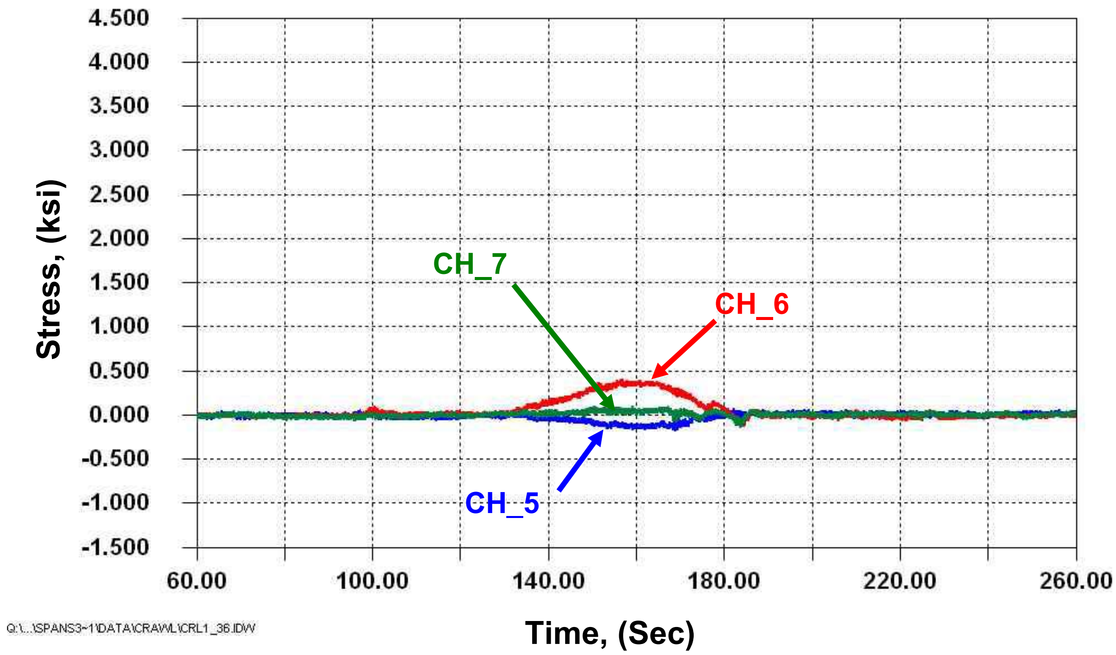


Figure 5.10 – Response of strain gages CH_5, CH_6 and CH_7 installed against the vertical angle element of the shear connector on the north shear connector, at the north end of the span over the east girder and on the west face of the shear connector plate in Span 36 as Truck 1 crossed in the northbound direction over the span in the outside lane during the controlled load test CRL1_36

Span 36, on the web plate of the shear connector near the north end of the plate and fit tight with the vertical angle element of the shear connector										
Test name	Truck in lane	CH_5, (ksi)			CH_6, (ksi)			CH_7, (ksi)		
		σ_{max}	σ_{min}	$\Delta\sigma$	σ_{max}	σ_{min}	$\Delta\sigma$	σ_{max}	σ_{min}	$\Delta\sigma$
CRL1_36	Truck 1, (O.L)	0.0	-0.2	0.2	0.4	0.0	0.4	0.0	0.0	0.0
	Truck 2, (O.L)	0.0	-0.1	0.1	0.4	0.0	0.4	0.1	0.0	0.1
	Truck 3, (M.L)	0.0	-0.5	0.5	0.3	0.0	0.3	0.2	0.0	0.2
	Truck 4, (M.L)	0.0	-0.6	0.6	0.2	0.0	0.2	0.3	0.0	0.3
	Truck 5, (I.L)	0.0	0.0	0.0	0.2	0.0	0.2	0.0	0.0	0.0
	Truck 6, (I.L)	0.0	-0.1	0.1	0.3	0.0	0.3	0.0	0.0	0.0
CRL2_36	Truck 1, (O.L)& Truck 2, (M.L)	0.0	-0.8	0.8	0.6	0.0	0.6	0.1	0.0	0.1
	Truck 3, (OL)& Truck 4, (ML)	0.0	-0.6	0.6	0.7	0.0	0.7	0.3	0.0	0.3
CRL3_36	Truck 5, (M.L)& Truck 6, (I.L)	0.0	-0.6	0.6	0.5	0.0	0.5	0.2	0.0	0.2
	Truck 1, (ML)& Truck 2, (IL)	0.0	-0.5	0.5	0.4	0.0	0.4	0.1	0.0	0.1
CRL4_36	Truck 3, (OL)& Truck 4, (ML) &Truck 5, (IL)	0.0	-0.6	0.6	0.8	0.0	0.8	0.3	0.0	0.3
	Truck 6, (O.L)& Truck 1, (M.L) &Truck 2, (I.L)	0.0	-0.6	0.6	1.0	0.0	1.0	0.3	0.0	0.3
M_36	Multiple presence	0.0	-0.4	0.4	0.9	0.0	0.9	0.1	0.0	0.1

Table 5.20 – Summary of peak stresses (ksi) measured in strain gages CH_5, CH_6 and CH_7 installed fit tight with the vertical angle element of the shear connector on the north shear connector, at the north end of the span over the east girder and on the west face of the shear connector plate in Span 36 as the test trucks crossed in the northbound direction over the span in the crawl tests

Span 36, on the web plate of the shear connector near the north end of the plate and fit tight with the vertical angle element of the shear connector										
Test name	**Truck in lane**	**CH_8, (ksi)**			**CH_9, (ksi)**			**CH_10, (ksi)**		
		σ_{max}	σ_{min}	$\Delta\sigma$	σ_{max}	σ_{min}	$\Delta\sigma$	σ_{max}	σ_{min}	$\Delta\sigma$
CRL1_36	**Truck 1, (O.L)**	0.2	0.0	0.2	0.5	0.0	0.5	0.0	-0.3	0.3
	Truck 2, (O.L)	0.1	0.0	0.1	0.5	0.0	0.5	0.0	-0.4	0.4
	Truck 3, (M.L)	0.1	0.0	0.1	0.3	0.0	0.3	0.0	-0.4	0.4
	Truck 4, (M.L)	0.1	0.0	0.1	0.2	0.0	0.2	0.0	-0.2	0.2
	Truck 5, (I.L)	0.0	0.0	0.0	0.4	0.0	0.4	0.0	-0.2	0.2
	Truck 6, (I.L)	0.0	0.0	0.0	0.4	0.0	0.4	0.0	-0.2	0.2
CRL2_36	**Truck 1, (O.L)& Truck 2, (M.L)**	0.4	0.0	0.4	0.6	0.0	0.6	0.0	-0.7	0.7
	Truck 3, (OL)& Truck 4, (ML)	0.5	0.0	0.5	0.8	0.0	0.8	0.0	-0.6	0.6
CRL3_36	**Truck 5, (M.L)& Truck 6, (I.L)**	0.1	0.0	0.1	0.5	0.0	0.5	0.0	-0.4	0.4
	Truck 1, (ML)& Truck 2, (IL)	0.2	0.0	0.2	0.4	0.0	0.4	0.0	-0.8	0.8
CRL4_36	**Truck 3, (OL)& Truck 4, (ML) &Truck 5, (IL)**	0.1	0.0	0.1	0.7	0.0	0.7	0.0	-0.7	0.7
	Truck 6, (O.L)& Truck 1, (M.L) &Truck 2, (I.L)	0.1	0.0	0.1	0.9	0.0	0.7	0.0	-0.9	0.9
M_36	**Multiple presence**	0.4	0.0	0.4	1.0	0.0	1.0	0.0	-0.9	0.9

Table 5.21 – Summary of peak stresses (ksi) measured in strain gages CH_8, CH_9 and CH_10 installed fit tight with the vertical angle element of the shear connector (back-to-back with gages CH_5, CH_6, and CH_7) on the north shear connector, at the north end of the span over the east girder and on the west face of the shear connector plate in Span 36 as the test trucks crossed in the northbound direction over the span in the crawl tests

Span 45, on the web plate of the shear connector near the north end of the plate and fit tight with the vertical angle element of the shear connector										
Test name	Truck in lane	CH_4, (ksi)			CH_5, (ksi)			CH_6, (ksi)		
		σ_{max}	σ_{min}	$\Delta\sigma$	σ_{max}	σ_{min}	$\Delta\sigma$	σ_{max}	σ_{min}	$\Delta\sigma$
CRL1_45	Truck 1, (O.L)	0.6	0.0	0.6	0.0	-1.4	1.4	0.0	-0.5	0.5
	Truck 2, (O.L)	0.5	0.0	0.5	0.0	-1.3	1.3	0.0	-0.4	0.4
	Truck 3, (M.L)	0.5	-1.4	1.4	0.0	-1.0	1.0	0.0	-0.4	0.4
	Truck 4, (M.L)	0.1	-2.0	2.0	0.0	-0.5	0.5	0.0	-1.2	1.2
	Truck 5, (I.L)	0.1	-0.5	0.5	0.0	-0.7	0.7	0.0	-0.2	0.2
	Truck 6, (I.L)	0.1	-0.5	0.5	0.0	-0.7	0.7	0.0	-0.2	0.2
CRL2_45	Truck 1, (O.L)& Truck 2, (M.L)	0.1	-2.2	2.2	0.0	-2.2	2.2	0.0	-0.8	0.8
	Truck 3, (OL)& Truck 4, (ML)	0.1	-2.6	2.6	0.0	-2.3	2.3	0.0	-0.8	0.8
CRL3_45	Truck 5, (M.L)& Truck 6, (I.L)	0.1	-1.8	1.8	0.0	-1.8	1.8	0.0	-0.6	0.6
	Truck 1, (ML)& Truck 2, (IL)	0.3	-0.6	0.6	0.0	-1.8	1.8	0.0	-0.6	0.6
[1]CRL4_45	Truck 3, (OL)& Truck 4, (ML) &Truck 5, (IL)	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Truck 6, (O.L)& Truck 1, (M.L) &Truck 2, (I.L)	NA	NA	NA	NA	NA	NA	NA	NA	NA
M_45	Multiple presence	0.3	-1.8	1.8	0.0	-2.9	2.9	0.0	-1.3	1.3

Note:
1. Data for this test were not retrieved

Table 5.22 – Summary of peak stresses (ksi) measured in strain gages CH_4, CH_5 and CH_6 installed fit tight with the vertical angle element of the shear connector on the north shear connector, at the north end of the span over the east girder and on the west face of the shear connector plate in Span 45 as the test trucks crossed in the northbound direction over the span in the crawl tests

Span 45, on the web plate of the shear connector near the north end of the plate and fit tight with the vertical angle element of the shear connector										
Test name	Truck in lane	CH_7, (ksi)			CH_8, (ksi)			CH_9, (ksi)		
		σ_{max}	σ_{min}	$\Delta\sigma$	σ_{max}	σ_{min}	$\Delta\sigma$	σ_{max}	σ_{min}	$\Delta\sigma$
CRL1_45	Truck 1, (O.L)	0.6	-0.5	1.1	0.0	-0.9	0.9	0.0	-1.0	1.0
	Truck 2, (O.L)	0.4	-0.4	0.8	0.0	-0.9	0.9	0.0	-1.0	1.0
	Truck 3, (M.L)	0.6	-0.8	0.8	0.0	-0.4	0.4	0.0	-0.7	0.7
	Truck 4, (M.L)	2.0	0.0	2.0	0.4	-0.6	0.6	0.0	-0.7	0.7
	Truck 5, (I.L)	0.6	0.0	0.6	0.0	-0.5	0.5	0.0	-0.6	0.6
	Truck 6, (I.L)	0.7	0.0	0.0	0.0	-0.5	0.5	0.0	-0.6	0.6
CRL2_45	Truck 1, (O.L)& Truck 2, (M.L)	1.9	0.0	1.9	0.0	-1.5	1.5	0.0	-1.7	1.7
	Truck 3, (OL)& Truck 4, (ML)	2.2	-0.7	0.7	0.0	-1.4	1.4	0.0	-1.6	1.6
CRL3_45	Truck 5, (M.L)& Truck 6, (I.L)	1.4	-0.7	0.7	0.1	-1.2	1.2	0.1	-1.4	1.4
	Truck 1, (ML)& Truck 2, (IL)	1.0	-0.6	0.6	0.1	-1.2	1.2	0.0	-1.3	1.3
[1]CRL4_45	Truck 3, (OL)& Truck 4, (ML) &Truck 5, (IL)	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Truck 6, (O.L)& Truck 1, (M.L) &Truck 2, (I.L)	NA	NA	NA	NA	NA	NA	NA	NA	NA
M_45	Multiple presence	2.4	0.0	2.4	0.0	-1.8	1.8	0.0	-2.0	2.0

Note:
1. Data for this test were not retrieved

Table 5.23 – Summary of peak stresses (ksi) measured in strain gages CH_7, CH_8 and CH_9 installed fit tight with the vertical angle element of the shear connector (back-to-back with gages CH_6, CH_7, and CH_8) on the north shear connector, at the north end of the span over the east girder and on the west face of the shear connector plate in Span 45 as the test trucks crossed in the northbound direction over the span in the crawl tests

5.3.8 Stresses in the Standing Angle Bolted to Shear Connector

Strain gages were installed on the vertical stiffener angle bolted to the web plate of the shear connector in Span 34, Span 36, and Span 45. The gages were installed on the vertical stiffener angle at mid height of the stiffener and mid width of the outstanding leg. The gages were installed back-to-back to capture any out-of-plane bending behavior of the stiffener angle.

As previously discussed, in Span 34, strain gage CH_27 was installed on the north face of the outstanding leg of the south end stiffener angle bolted to the web of the shear connector at the north end of the span over the east girder.

In Span 36, strain gage CH_3 and CH_4 was installed back-to-back on the south and north face, respectively, of the outstanding leg of the north end stiffener angle bolted to the web of the shear connector at the north end of the span over the east girder.

In Span 45, strain gage CH_10 and CH_11 were installed back-to-back on the south and north face, respectively, of the north end stiffener angle bolted to the web of the shear connector at the south end of the span over the east girder. Strain gage CH_38 was installed in the same span on the north face of the outstanding leg of the south end stiffener angle bolted to the web of the shear connector at the north end of the span over the east girder.

This detail is classified as Category A detail per AASHTO Specifications with constant amplitude fatigue limit (CAFL) of 24 ksi. All stresses measured during the controlled crawl tests were significantly lower than the CAFL of the detail as shown in Table 5.23 and Table 5.24. The maximum stress range value measured during the crawl tests was recorded by strain gage CH_38 installed in Span 45 and was equal to 1.5 ksi.

Figure 5.10 presents the response of strain gages CH_3 and CH_4 installed back-to-back on the outstanding leg of the north end stiffener angle bolted to the web of the shear connector at the north end of the span over the east girder as Truck 1 crossed over the span in the outside lane during the controlled load test CRL1_36. Except for the last portion of the curve (time 170 sec to time 185 sec), Figure 5.10 shows that the magnitude of the response in both gages was almost the same indicating the in-plane bending was the dominate response of both gages. Opposite sign in the response of the gages in the last portion of the curve indicates out-of-plane bending of the vertical stiffener.

Summaries of the maximum stress, minimum stress, and stress range values experienced by the gages in the crawl tests, including the multiple presence truck test are presented in Tables 5.23 and 5.24. Strain gage CH_27 was damage in the installation process and therefore, the results of that gage will not be included.

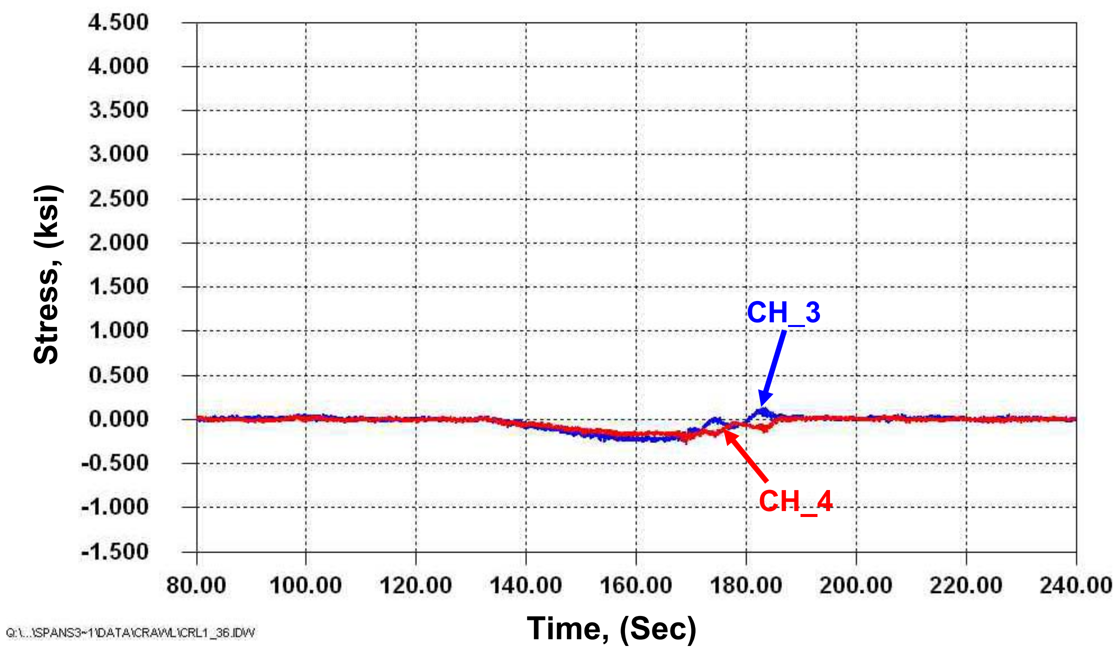


Figure 5.10 – Response of strain gages CH_3 and CH_4 installed back-to-back on the outstanding leg of the north end stiffener angle (at mid height of the stiffener and mid width of the outstanding leg) bolted to the web of the shear connector at the north end of the span over the east girder as Truck 1 crossed in the northbound direction over the span in the outside lane during the controlled load test CRL1_36.

Span 36, outstanding leg of the south end stiffener angle bolted to the web of the shear connector							
Test name	Truck in lane	CH_3, (ksi)			CH_4, (ksi)		
		σ_{max}	σ_{min}	$\Delta\sigma$	σ_{max}	σ_{min}	$\Delta\sigma$
CRL1_36	Truck 1, (O.L)	0.1	-0.3	0.3	0.0	-0.3	0.3
	Truck 2, (O.L)	0.1	-0.3	0.3	0.0	-0.2	0.2
	Truck 3, (M.L)	0.0	-0.2	0.2	0.1	-0.1	0.1
	Truck 4, (M.L)	0.0	-0.2	0.2	0.2	-0.1	0.3
	Truck 5, (I.L)	0.0	-0.1	0.1	0.0	-0.1	0.1
	Truck 6, (I.L)	0.0	-0.1	0.1	0.0	-0.1	0.1
CRL2_36	Truck 1, (O.L)& Truck 2, (M.L)	0.0	-0.7	0.7	0.0	-0.5	0.5
	Truck 3, (OL)& Truck 4, (ML)	0.0	-0.5	0.5	0.0	-0.4	0.4
CRL3_36	Truck 5, (M.L)& Truck 6, (I.L)	0.0	-0.7	0.7	0.0	-0.3	0.3
	Truck 1, (ML)& Truck 2, (IL)	0.0	-0.4	0.4	0.0	-0.4	0.4
CRL4_36	Truck 3, (OL)& Truck 4, (ML) &Truck 5, (IL)	0.0	-0.9	0.9	0.2	-0.4	0.4
	Truck 6, (O.L)& Truck 1, (M.L) &Truck 2, (I.L)	0.0	-0.7	0.7	0.2	-0.4	0.4
M_36	Multiple presence	0.0	-0.5	0.5	0.0	-0.4	0.4

Table 5.23 – Summary of peak stresses (ksi) measured in strain gages CH_3 and CH_4 back-to-back on the south and north face, respectively, of the outstanding leg of the north end stiffener angle bolted to the web of the shear connector at the north end of the span over the east girder in Span 36 as the test trucks crossed in the northbound direction over the span in the crawl tests

Span 45, outstanding leg of the south end stiffener angle bolted to the web of the shear connector										
Test name	Truck in lane	CH_10, (ksi)			CH_11, (ksi)			CH_38, (ksi)		
		σ_{max}	σ_{min}	$\Delta\sigma$	σ_{max}	σ_{min}	$\Delta\sigma$	σ_{max}	σ_{min}	$\Delta\sigma$
CRL1_45	Truck 1, (O.L)	0.5	-0.4	0.9	0.3	0.0	0.3	0.3	0.0	0.3
	Truck 2, (O.L)	0.4	-0.3	0.7	0.3	0.0	0.3	0.4	0.0	0.4
	Truck 3, (M.L)	0.4	-0.2	0.6	0.2	-0.2	0.4	0.1	-0.6	0.7
	Truck 4, (M.L)	0.7	0.0	0.7	0.2	-0.4	0.6	0.2	-0.8	1.0
	Truck 5, (I.L)	0.3	0.0	0.3	0.2	0.0	0.2	0.1	-0.2	0.3
	Truck 6, (I.L)	0.3	0.0	0.3	0.2	0.0	0.2	0.1	-0.2	0.3
CRL2_45	Truck 1, (O.L)& Truck 2, (M.L)	0.7	-0.1	0.8	0.4	-0.3	0.7	0.3	-1.2	1.5
	Truck 3, (OL)& Truck 4, (ML)	0.8	-0.4	1.2	0.4	-03	0.7	0.3	-1.2	1.5
CRL3_45	Truck 5, (M.L)& Truck 6, (I.L)	0.6	-0.5	1.1	0.4	0.0	0.4	0.3	-1.2	1.5
	Truck 1, (ML)& Truck 2, (IL)	0.5	-0.8	1.3	0.4	0.0	0.4	0.3	-1.2	1.5
[1]CRL4_45	Truck 3, (OL)& Truck 4, (ML) &Truck 5, (IL)	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Truck 6, (O.L)& Truck 1, (M.L) &Truck 2, (I.L)	NA	NA	NA	NA	NA	NA	NA	NA	NA
M_45	Multiple presence	0.8	-0.2	1.0	0.7	0.0	0.7	0.5	-1.0	1.5

Note:
1. Data for this test were not retrieved

Table 5.24 – Summary of peak stresses (ksi) measured in strain gages CH_10, CH_11, and CH_38 installed on the outstanding legs of the north and south end stiffener angles bolted to the web of the shear connector at the north end of the span over the east girder in Span 45 as the test trucks crossed in the northbound direction over the span in the crawl tests

5.3.9 Stresses in the Underside of Deck Plate at the Termination of the Welded and Bolted Shear Connectors

Welded and bolted details were used for attaching/connecting the prototype longitudinal shear connectors to the bottom face of the deck plate. Strain gages were installed on the bottom face of the deck plate at the termination of the bolted and welded shear connectors to measure the nominal stress range in the deck plate near the details. In Span 34, strain gage CH_28 was installed transversely on the bottom face of the deck plate at 2 in off-center from the shear connector web near the south end of the north shear connector installed in the span over the east girder. At the south end termination of the same shear connector, strain gage CH_29 was installed longitudinally on the bottom face of the deck plate at 1 1/2 in from the termination of the longitudinal shear connector weld.

In Span 36, strain gage CH_2 was installed on the bottom face of the deck plate at the north end termination of the north shear connector located above the east girder. The strain gage was installed longitudinally on the bottom face of the steel deck plate at 1 1/2" from the termination of the shear connector bolted connection (shear connector bolted to the bottom face of the deck plate).

In Span 45, strain gage CH_32 was installed transversely on the bottom face of the deck plate at 2 in off-center from the shear connector web near the south end of the north shear connector installed over the east girder. At the south end termination of the same shear connector, strain gage CH_37 was installed longitudinally on the bottom face of the deck plate at 1 1/2" from the termination of the shear connector longitudinal weld.

Strain gages CH_28, CH_29, CH_32 and CH_37 are classified as Category C detail per AASHTO Specifications with CAFL of 10 ksi. The response of strain gage CH_28 installed transversely on the bottom face of the deck plate at 2 in off-center from the shear connector web as Truck 1 crossed over Span 34 in the controlled load test CRL1_34 is shown in Figure 5.11. Figure 5.12 shows the response of strain gage CH_29 installed longitudinally on the bottom face of the deck plate at 1 1/2" from the termination of the longitudinal shear connector weld as Truck 1 crossed over Span 34 in the controlled load test CRL1_34.

The detail where strain gage CH_2 was installed is classified as Category C detail per AASHTO Specifications. The response of CH_2 to the crossing of Truck 1 in the outside lane in controlled load test CRL1_36 is shown in Figure 5.13. As the figure shows, low response was measured during the crossing of the truck. However, when the transverse position of the test truck was changed (i.e., Truck 3 in the middle lane instead of Truck 1 in the outside lane), the response measured by the strain gage was significantly higher as shown in Figure 5.14. The figure also shows the effect of the transverse position of the truck on the response as each axle of the truck produced a stress cycle.

Summaries of the maximum stress, minimum stress, and stress range values experienced by all of the gages noted above in the crawl tests, including the multiple presence truck test are presented in Tables 5.25 through 5.29. As indicated in the tables, the maximum stress ranges measured during the controlled crawl tests were 1.7 ksi, 0.9 ksi, 2.0 ksi, 2.0 ksi, and 2.0 ksi, recorded by strain gages CH_28, CH_29, CH_2, CH_32, and CH_37, respectively. These values are well below the CAFL of the detail (10 ksi).

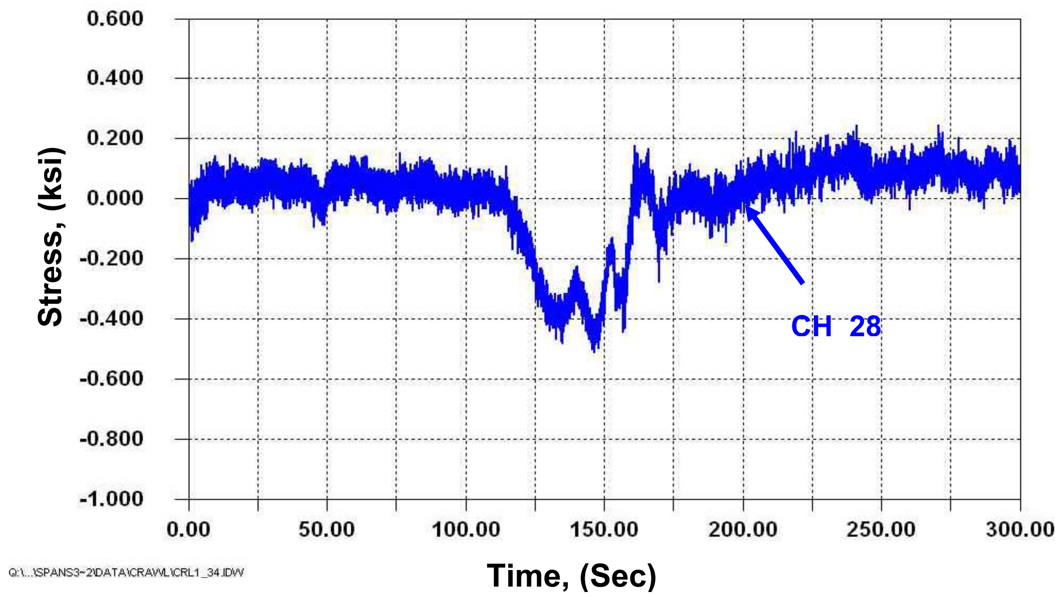


Figure 5.11 – Response of strain gage CH_28 installed transversely on the bottom face of the deck plate at 2 in off-center from the shear connector web in Span 34 as Truck 1 crossed in the northbound direction over the span in the outside lane in the controlled load test CRL1_34

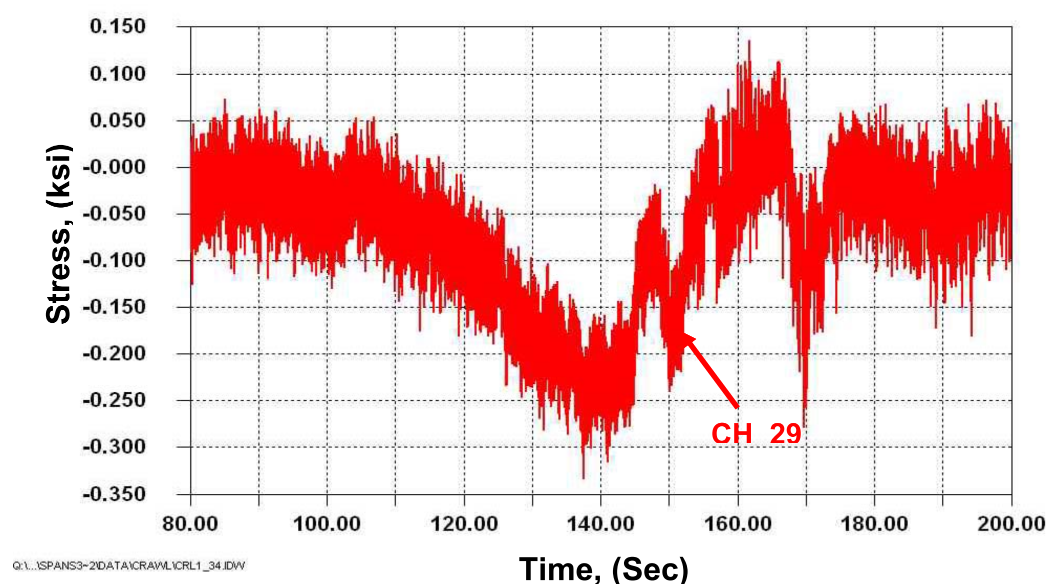


Figure 5.12 – Response of strain gage CH_29 installed longitudinally on the bottom face of the deck plate at 1 1/2" from the termination of the longitudinal shear connector weld in Span 34 as Truck 1 crossed in the northbound direction over the span in the outside lane in the controlled load test CRL1_34

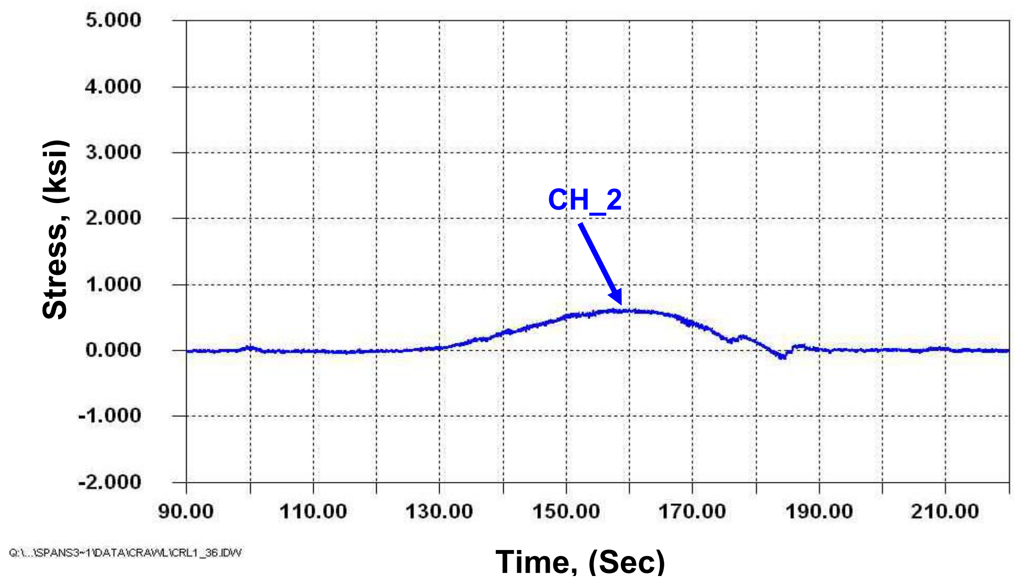


Figure 5.13 – Response of strain gage CH_2 installed on the bottom face of the deck plate at the north end termination of the north shear connector located above the east girder in Span 36 as Truck 1 crossed in the northbound direction over the span in the outside lane in the controlled load test CRL1_36

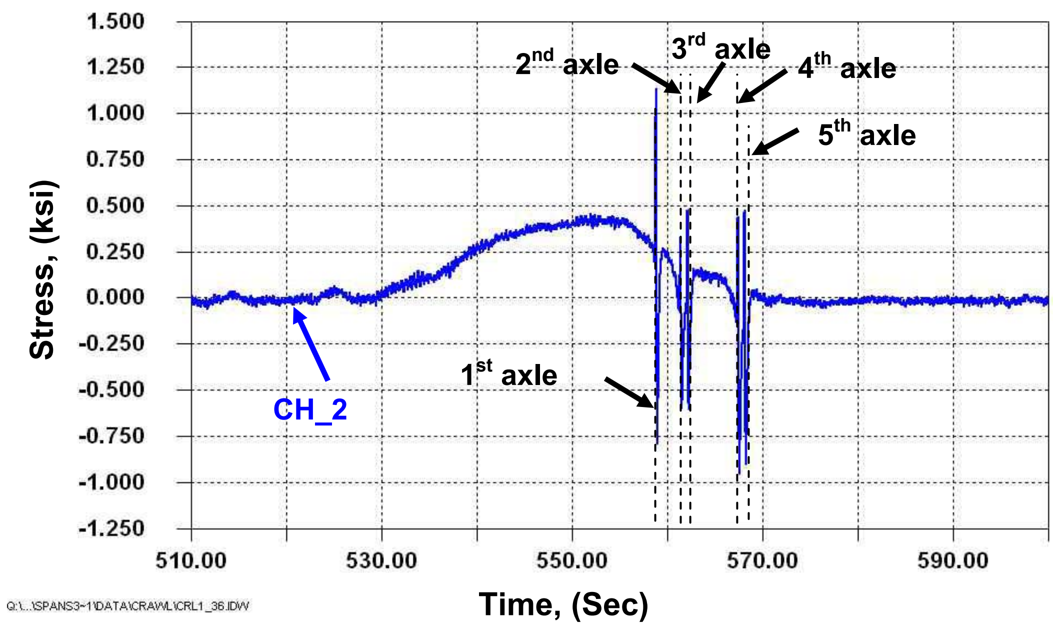


Figure 5.14 – Response of strain gage CH_2 installed on the bottom face of the deck plate at the north end termination of the north shear connector located above the east girder in Span 36 as Truck 3 crossed in the northbound direction over the span in the outside lane in the controlled load test CRL1_36

Span 34, transversely on the bottom face of the deck plate off-center from the shear connector web				
Test name	**Truck in lane**	**CH_28, (ksi)**		
		σ_{max}	σ_{min}	$\Delta\sigma$
CRL1_34	**Truck 1, (O.L)**	0.0	-0.5	0.5
	Truck 2, (O.L)	0.0	-0.5	0.5
	Truck 3, (M.L)	0.0	-1.1	1.1
	Truck 4, (M.L)	0.0	-1.0	1.0
	Truck 5, (I.L)	0.0	-0.3	0.3
	Truck 6, (I.L)	0.0	-0.3	0.3
CRL2_34	**Truck 1, (O.L)& Truck 2, (M.L)**	0.0	-1.5	1.5
	Truck 3, (OL)& Truck 4, (ML)	0.0	-1.5	1.5
CRL3_34	**Truck 5, (M.L)& Truck 6, (I.L)**	0.0	-1.5	1.5
	Truck 1, (ML)& Truck 2, (IL)	0.0	-1.5	1.5
CRL4_34	**Truck 3, (OL)& Truck 4, (ML) &Truck 5, (IL)**	0.0	-1.7	1.7
	Truck 6, (O.L)& Truck 1, (M.L) &Truck 2, (I.L)	0.0	-1.7	1.7
M_34	**Multiple presence**	0.0	-1.7	1.7

Table 5.25 – Summary of peak stresses (ksi) measured in strain gages CH_28 installed transversely on the bottom face of the deck plate at 2 in off-center from the shear connector web near the south end of the north shear connector installed in the span over the east girder in Span 34 as the test trucks crossed in the northbound direction over the span in the crawl tests

Span 34, longitudinally on the bottom face of the deck plate at the termination of the longitudinal shear connector weld				
Test name	Truck in lane	CH_29, (ksi)		
		σ_{max}	σ_{min}	$\Delta\sigma$
CRL1_34	Truck 1, (O.L)	0.1	-0.3	0.4
	Truck 2, (O.L)	0.1	-0.2	0.3
	Truck 3, (M.L)	0.3	-0.2	0.5
	Truck 4, (M.L)	0.3	-0.2	0.5
	Truck 5, (I.L)	0.0	-0.3	0.3
	Truck 6, (I.L)	0.0	-0.3	0.3
CRL2_34	Truck 1, (O.L)& Truck 2, (M.L)	0.2	-0.5	0.7
	Truck 3, (OL)& Truck 4, (ML)	0.1	-0.5	0.6
CRL3_34	Truck 5, (M.L)& Truck 6, (I.L)	0.2	-0.3	0.5
	Truck 1, (ML)& Truck 2, (IL)	0.1	-0.4	0.5
CRL4_34	Truck 3, (OL)& Truck 4, (ML) &Truck 5, (IL)	0.3	-0.5	0.8
	Truck 6, (O.L)& Truck 1, (M.L) &Truck 2, (I.L)	0.3	-0.5	0.8
M_34	Multiple presence	0.2	-0.7	0.9

Table 5.26 – Summary of peak stresses (ksi) measured in strain gages CH_29 installed longitudinally on the bottom face of the deck plate at 1 1/2" from the termination of the longitudinal shear connector weld at the south end of the north shear connector installed over the east girder in Span 34 as the test trucks crossed in the northbound direction over the span in the crawl tests

Span 36, longitudinally on the bottom face of the deck plate at the termination of the shear connector				
Test name	Truck in lane	CH_2, (ksi)		
		σ_{max}	σ_{min}	$\Delta\sigma$
CRL1_36	Truck 1, (O.L)	0.6	-0.1	0.7
	Truck 2, (O.L)	0.6	-0.1	0.7
	Truck 3, (M.L)	1.1	-0.8	1.9
	Truck 4, (M.L)	0.5	-1.0	1.5
	Truck 5, (I.L)	0.4	-0.1	0.5
	Truck 6, (I.L)	0.4	-0.1	0.5
CRL2_36	Truck 1, (O.L)& Truck 2, (M.L)	0.9	-1.0	2.0
	Truck 3, (OL)& Truck 4, (ML)	0.4	-0.8	1.2
CRL3_36	Truck 5, (M.L)& Truck 6, (I.L)	1.0	-0.8	1.8
	Truck 1, (ML)& Truck 2, (IL)	1.2	-0.4	1.6
CRL4_36	Truck 3, (OL)& Truck 4, (ML) &Truck 5, (IL)	1.2	-0.2	1.4
	Truck 6, (O.L)& Truck 1, (M.L) &Truck 2, (I.L)	0.8	-1.1	1.9
M_36	Multiple presence	1.4	0.0	1.4

Table 5.27 – Summary of peak stresses (ksi) measured in strain gages CH_2 installed on the bottom face of the deck plate at the north end termination of the north shear connector located above the east girder in Span 36 as the test trucks crossed in the northbound direction over the span in the crawl tests

Span 45, transversely on the bottom face of the deck plate at off-center from the shear connector web				
Test name	Truck in lane	CH_32, (ksi)		
		σ_{max}	σ_{min}	$\Delta\sigma$
CRL1_45	Truck 1, (O.L)	0.0	-1.0	1.0
	Truck 2, (O.L)	0.0	-1.1	1.1
	Truck 3, (M.L)	0.0	-1.5	1.5
	Truck 4, (M.L)	0.0	-1.6	1.6
	Truck 5, (I.L)	0.0	-0.6	0.6
	Truck 6, (I.L)	0.0	-0.6	0.6
CRL2_45	Truck 1, (O.L)& Truck 2, (M.L)	0.0	-1.8	1.8
	Truck 3, (OL)& Truck 4, (ML)	0.0	-1.8	1.8
CRL3_45	Truck 5, (M.L)& Truck 6, (I.L)	0.0	-1.5	1.5
	Truck 1, (ML)& Truck 2, (IL)	0.0	-1.5	1.5
[1]CRL4_45	Truck 3, (OL)& Truck 4, (ML) &Truck 5, (IL)	NA	NA	NA
	Truck 6, (O.L)& Truck 1, (M.L) &Truck 2, (I.L)	NA	NA	NA
M_45	Multiple presence	0.0	-2.0	2.0

Note:
1. Data for this test were not retrieved

Table 5.28 – Summary of peak stresses (ksi) measured in strain gages CH_32 installed transversely on the bottom face of the deck plate at 2 in off-center from the shear connector web near the south end of the north shear connector installed over the east girder in Span 45 as the test trucks crossed in the northbound direction over the span in the crawl tests

Span 45, longitudinally on the bottom face of the deck plate at the termination of the longitudinal shear connector weld				
Test name	Truck in lane	CH_37, (ksi)		
		σ_{max}	σ_{min}	$\Delta\sigma$
CRL1_45	Truck 1, (O.L)	0.0	-0.3	0.3
	Truck 2, (O.L)	0.0	-0.4	0.4
	Truck 3, (M.L)	1.3	-0.7	2.0
	Truck 4, (M.L)	1.4	-0.5	1.9
	Truck 5, (I.L)	0.0	-0.2	0.2
	Truck 6, (I.L)	0.0	-0.2	0.2
CRL2_45	Truck 1, (O.L)& Truck 2, (M.L)	1.3	-0.5	1.8
	Truck 3, (OL)& Truck 4, (ML)	1.2	-0.5	1.7
CRL3_45	Truck 5, (M.L)& Truck 6, (I.L)	0.8	-0.5	1.3
	Truck 1, (ML)& Truck 2, (IL)	1.3	-0.5	1.8
[1]CRL4_45	Truck 3, (OL)& Truck 4, (ML) &Truck 5, (IL)	NA	NA	NA
	Truck 6, (O.L)& Truck 1, (M.L) &Truck 2, (I.L)	NA	NA	NA
M_45	Multiple presence	1.0	-0.4	1.4

Note:
1. Data for this test were not retrieved

Table 5.29 – Summary of peak stresses (ksi) measured in strain gages CH_37 installed longitudinally on the bottom face of the deck plate at 1 1/2" from the south termination of longitudinal weld of the north shear connector located at the north end of Span 45 as the test trucks crossed in the northbound direction over the span in the crawl tests

5.3.10 Stresses in the Web of Existing Sub-floorbeam near Blocked Flange at Sub-floorbeam-to-Stringer Connection

As previously discussed, cracking has been observed at the two northern-most sub-floorbeams and the two southern-most sub-floorbeams in many of the approach spans. The cracks appear to have originated at the reentrant corner of the flame cut blocked top flange and propagated downwards in the web of the sub-floorbeam. The notch and the reentrant corner condition of the detail would not provide more than a Category E' fatigue resistance, that otherwise could have been a Category A if properly fabricated.

To assess the reason for cracking, biaxial strain gages were installed back-to-back on the web of existing Sub-floorbeam 8, 1 in below the blocked flange (between Rib 5 and Stringer 3). Specifically, in Span 34, strain gages CH_13 and CH_14 were installed horizontally and vertically, respectively, on the south face of the web of the sub-floorbeam. Strain gages CH_15 and CH_16 were installed on the north face of the web directly behind gages CH_13 and CH_14.

In Span 35, biaxial strain gages were also installed back-to-back on the web of existing Sub-floorbeam 2 between Rib 5 and Stringer 3. However, because of the existence of cracks at the other locations to be instrumented, the gages were installed at 2 3/4 in below the blocked flange instead of 1 in as the case in Span 34. Strain gages CH_44 and CH_45 were installed horizontally and vertically, respectively, on the south face of the web of the sub-floorbeam. Strain gages CH_46 and CH_47 were installed on the north face of the web directly behind gages CH_44 and CH_45.

In Span 38, the gages were installed on the web of existing Sub-floorbeam 2 between Rib 5 and Stringer 3. The biaxial gages were installed back-to-back on the web at 1 in directly below the blocked flange. Strain gages CH_48 and CH_49 were installed horizontally and vertically, respectively, on the south face of the web of the sub-floorbeam. Strain gages CH_50 and CH_51 were installed on the north face of the web directly behind gages CH_48 and CH_49.

The response of strain gages CH_48 and CH_49 to the crossing of the three test trucks (Truck 3, Truck 4, and Truck 5, all side-by-side) over the span during crawl test CRL4_36 is shown in Figure 5.15. As shown in the figure, the response of strain gage CH_48, which was installed horizontally in the longitudinal direction of the sub-floorbeam web, is significantly higher than the response in strain gage CH_49 installed on the sub-floorbeam web in the transverse direction (vertically). It is important to note however that in some cases, for a given instrumented location, the response of the strain gage installed vertically was higher than the response of the strain gage installed horizontally.

Summaries of the maximum stress, minimum stress, and stress range values experienced by the gages in the crawl tests, including the multiple presence truck test are presented in Tables 5.30 through 5.35.

As clearly shown in the tables, the response of the strain gages installed on Sub-floorbeam 2 in Span 38 is significantly higher the response of the strain gages installed at comparable location in Span 34 and Span 35. Such observation indicates that the prototype retrofits installed in Span 34 and Span 35 were very effective in reducing the out-of-plane displacement in the sub-floorbeams.

In Span 34, the highest response was typically measured by strain gage CH_13. The maximum stress range measured by the gage was found to be equal to 3.3 ksi, which is approximately 50% less the stress range value of 6.4 ksi measured by strain gage CH_48 during the same controlled (strain gage CH_48 was installed in Span 38 at approximately 1 3/4 in lower than the location of strain gage CH_13 installed in Span 34). The maximum stress range measured by gages CH_14, CH_15, and CH_16 was found to be equal to 1.2 ksi. It is important to note that the only prototype retrofit installed in Span 34 was the prototype shear connectors.

In Span 35, the stress range measured by strain gage CH_44, installed at comparable location to strain gages CH_13 and CH_48, was found to be equal to 0.3 ksi, which is considerably low. The span was retrofitted with different prototype repair types for the web of end and intermediate floorbeams.

Since the location of the strain gages installed in Span 35 is slightly different than the location of the gages installed in Span 34, it is difficult to make direct comparison between the effectiveness of the prototype retrofits installed in Span 34 and Span 35 in reducing the out-of-plane stresses in the sub-floorbeam web. It is however clear that the response of the gages in either of the spans is significantly lower than the gages installed in Span 38.

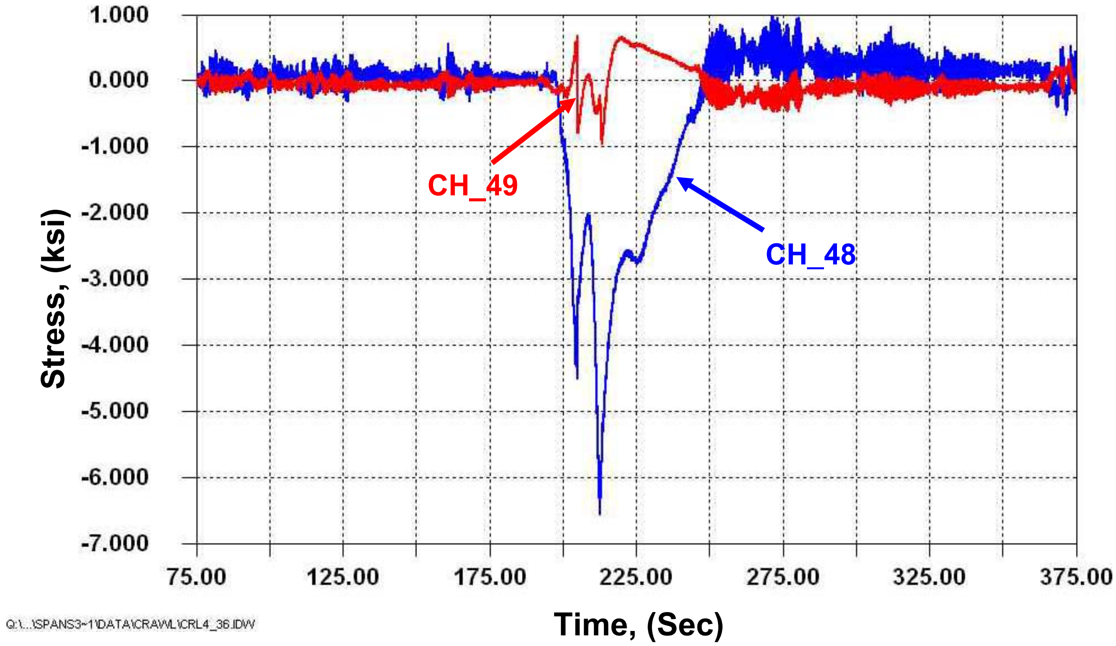


Figure 5.15 – Response of strain gages CH_48 and CH_49 installed horizontally and vertically, respectively, on the south face of the web of the Sub-floorbeam 2 in Span 38 as Trucks 3, 4, and 5 crossed in the northbound direction over the span in the controlled load test CRL4_36

Span 34, web of existing sub-floorbeams near web/flange cutout at sub-floorbeam-to-stringer connection							
Test name	Truck in lane	CH_13, (ksi)			CH_14, (ksi)		
		σ_{max}	σ_{min}	$\Delta\sigma$	σ_{max}	σ_{min}	$\Delta\sigma$
CRL1_34	Truck 1, (O.L)	1.6	0.0	1.6	0.2	-0.3	0.5
	Truck 2, (O.L)	1.8	0.0	1.8	0.2	-0.3	0.5
	Truck 3, (M.L)	0.9	-1.4	2.3	--	--	--
	Truck 4, (M.L)	0.6	-1.0	1.6	--	--	--
	Truck 5, (I.L)	0.4	0.0	0.4	--	--	--
	Truck 6, (I.L)	0.4	0.0	0.4	--	--	--
CRL2_34	Truck 1, (O.L)& Truck 2, (M.L)	2.1	-1.2	3.3	0.3	-0.5	0.8
	Truck 3, (OL)& Truck 4, (ML)	2.3	-0.8	3.1	0.3	-0.5	0.8
CRL3_34	Truck 5, (M.L)& Truck 6, (I.L)	1.0	-1.4	2.4	--	--	--
	Truck 1, (ML)& Truck 2, (IL)	0.9	-1.5	2.4	--	--	--
CRL4_34	Truck 3, (OL)& Truck 4, (ML) &Truck 5, (IL)	1.4	-0.4	1.8	--	--	--
	Truck 6, (O.L)& Truck 1, (M.L) &Truck 2, (I.L)	2.0	-0.9	2.9	--	--	--
M_34	Multiple presence	1.7	-0.9	2.6	0.4	-0.7	1.1

Note:
"--" indicates significant noise in the data.

Table 5.30 – Summary of peak stresses (ksi) measured in strain gages CH_13 and CH_14 installed horizontally and vertically, respectively, on the south face of the web of Sub-floorbeam 8 and 1 in below the web/flange cutout (between Rib 5 and Stringer 3) in Span 34 as the test trucks crossed in the northbound direction over the span in the crawl tests

Span 34, web of existing sub-floorbeams near web/flange cutout at sub-floorbeam-to-stringer connection							
Test name	**Truck in lane**	**CH_15, (ksi)**			**CH_16, (ksi)**		
		σ_{max}	σ_{min}	$\Delta\sigma$	σ_{max}	σ_{min}	$\Delta\sigma$
CRL1_34	**Truck 1, (O.L)**	0.4	0.0	0.4	0.4	-0.2	0.6
	Truck 2, (O.L)	0.4	0.0	0.4	0.5	-0.2	0.7
	Truck 3, (M.L)	0.0	0.0	0.0	0.3	-0.2	0.5
	Truck 4, (M.L)	0.0	0.0	0.0	0.3	-0.2	0.5
	Truck 5, (I.L)	0.0	0.0	0.0	0.1	-0.2	0.3
	Truck 6, (I.L)	0.0	0.0	0.0	0.1	-0.2	0.3
CRL2_34	**Truck 1, (O.L)& Truck 2, (M.L)**	0.5	-0.1	0.6	0.6	-0.4	1.0
	Truck 3, (OL)& Truck 4, (ML)	0.5	-0.1	0.6	0.4	-0.4	0.8
CRL3_34	**Truck 5, (M.L)& Truck 6, (I.L)**	0.0	-0.4	0.4	0.1	-0.3	0.4
	Truck 1, (ML)& Truck 2, (IL)	0.0	-0.5	0.5	0.2	-0.6	0.8
CRL4_34	**Truck 3, (OL)& Truck 4, (ML) &Truck 5, (IL)**	--	--	--	--	--	--
	Truck 6, (O.L)& Truck 1, (M.L) &Truck 2, (I.L)	--	--	--	--	--	--
M_34	**Multiple presence**	0.3	-0.2	0.5	0.6	-0.6	1.2

Note:
"--" indicates significant noise in the data.

Table 5.31 – Summary of peak stresses (ksi) measured in strain gages CH_15 and CH_16 installed horizontally and vertically, respectively, on the north face of the web of Sub-floorbeam 8 and 1 in below the web/flange cutout (between Rib5 and Stringer 3) in Span 34 as the test trucks crossed in the northbound direction over the span in the crawl tests

Span 35, web of existing sub-floorbeams near web/flange cutout at sub-floorbeam-to-stringer connection							
Test name	Truck in lane	CH_44, (ksi)			CH_45, (ksi)		
		σ_{max}	σ_{min}	$\Delta\sigma$	σ_{max}	σ_{min}	$\Delta\sigma$
CRL1_34	Truck 1, (O.L)	0.0	0.0	0.0	0.0	-0.3	0.3
	Truck 2, (O.L)	0.0	0.0	0.0	0.2	-0.2	0.4
	Truck 3, (M.L)	0.0	0.0	0.0	0.1	-0.3	0.4
	Truck 4, (M.L)	0.0	0.0	0.0	0.1	-0.2	0.3
	Truck 5, (I.L)	0.0	0.0	0.0	0.1	-0.1	0.2
	Truck 6, (I.L)	0.0	0.0	0.0	0.1	-0.1	0.2
CRL2_34	Truck 1, (O.L)& Truck 2, (M.L)	0.2	0.0	0.2	0.2	-0.5	0.7
	Truck 3, (OL)& Truck 4, (ML)	0.2	-0.1	0.3	0.2	-0.4	0.6
CRL3_34	Truck 5, (M.L)& Truck 6, (I.L)	--	--	--	--	--	--
	Truck 1, (ML)& Truck 2, (IL)	--	--	--	--	--	--
CRL4_34	Truck 3, (OL)& Truck 4, (ML) &Truck 5, (IL)	0.2	0.0	0.2	0.1	-0.6	0.7
	Truck 6, (O.L)& Truck 1, (M.L) &Truck 2, (I.L)	0.2	0.0	0.2	0.1	-0.5	0.6
M_34	Multiple presence	0.3	0.0	0.3	0.1	-0.4	0.5

Note:
“--" indicates significant noise in the data.

Table 5.32 – Summary of peak stresses (ksi) measured in strain gages CH_44 and CH_45 installed horizontally and vertically, respectively, on the south face of the web of Sub-floorbeam 2 and at 2 3/4 in below the web/flange (between Rib 5 and Stringer 3) in Span 35 as the test trucks crossed in the northbound direction over the span in the crawl tests

Span 35, web of existing sub-floorbeams near web/flange cutout at sub-floorbeam-to-stringer connection							
Test name	**Truck in lane**	**CH_46, (ksi)**			**CH_47, (ksi)**		
		σ_{max}	σ_{min}	$\Delta\sigma$	σ_{max}	σ_{min}	$\Delta\sigma$
CRL1_34	**Truck 1, (O.L)**	0.0	0.0	0.0	0.5	0.0	0.5
	Truck 2, (O.L)	0.0	0.0	0.0	0.5	0.0	0.5
	Truck 3, (M.L)	0.0	0.0	0.0	0.3	0.0	0.3
	Truck 4, (M.L)	0.0	0.0	0.0	0.3	0.0	0.3
	Truck 5, (I.L)	0.0	0.0	0.0	0.3	0.0	0.3
	Truck 6, (I.L)	0.0	0.0	0.0	0.3	0.0	0.3
CRL2_34	**Truck 1, (O.L)& Truck 2, (M.L)**	0.2	0.0	0.2	0.8	0.0	0.8
	Truck 3, (OL)& Truck 4, (ML)	0.1	-0.1	0.2	0.7	0.0	0.7
CRL3_34	**Truck 5, (M.L)& Truck 6, (I.L)**	0.0	0.0	0.0	0.4	0.0	0.4
	Truck 1, (ML)& Truck 2, (IL)	0.0	0.0	0.0	0.4	0.0	0.4
CRL4_34	**Truck 3, (OL)& Truck 4, (ML) &Truck 5, (IL)**	0.0	-0.2	0.2	0.8	0.0	0.8
	Truck 6, (O.L)& Truck 1, (M.L) &Truck 2, (I.L)	0.0	-0.2	0.2	0.8	0.0	0.8
M_34	**Multiple presence**	0.0	0.0	0.0	0.8	0.0	0.8

Table 5.33 – Summary of peak stresses (ksi) measured in strain gages CH_46 and CH_47 installed horizontally and vertically, respectively, on the south face of the web of Sub-floorbeam 2 and at 2 3/4 in below the web/flange (between Rib 5 and Stringer 3) in Span 35 as the test trucks crossed in the northbound direction over the span in the crawl tests

Span 38, web of existing sub-floorbeams near web/flange cutout at sub-floorbeam-to-stringer connection							
Test name	Truck in lane	CH_48, (ksi)			CH_49, (ksi)		
		σ_{max}	σ_{min}	$\Delta\sigma$	σ_{max}	σ_{min}	$\Delta\sigma$
CRL1_36	Truck 1, (O.L)	0.3	-2.5	2.8	0.4	-0.2	0.6
	Truck 2, (O.L)	0.3	-2.5	2.8	0.4	-0.2	0.6
	Truck 3, (M.L)	0.4	-3.2	3.6	0.4	-0.6	1.0
	Truck 4, (M.L)	0.4	-3.5	3.9	0.4	-0.7	1.1
	Truck 5, (I.L)	0.2	-1.0	1.2	0.4	-0.1	0.5
	Truck 6, (I.L)	0.2	-1.0	1.2	0.4	-0.1	0.5
CRL2_36	Truck 1, (O.L)& Truck 2, (M.L)	0.4	-6.0	6.4	0.8	-0.7	1.5
	Truck 3, (OL)& Truck 4, (ML)	0.4	-6.5	6.9	0.8	-0.9	1.7
CRL3_36	Truck 5, (M.L)& Truck 6, (I.L)	0.2	-2.8	3.0	0.5	-0.7	1.2
	Truck 1, (ML)& Truck 2, (IL)	0.1	-1.7	1.8	0.4	-0.1	0.5
CRL4_36	Truck 3, (OL)& Truck 4, (ML) &Truck 5, (IL)	0.6	-6.6	7.2	0.7	-1.0	1.7
	Truck 6, (O.L)& Truck 1, (M.L) &Truck 2, (I.L)	0.7	-5.8	6.5	0.7	-0.8	1.5
M_36 (raw)	Multiple presence	4.6	-1.9	6.5	0.4	-1.8	2.2
M_36 (modified)	Multiple presence	0.3	-6.3	6.6	1.8	-0.4	2.2

Table 5.34 – Summary of peak stresses (ksi) measured in strain gages CH_48 and CH_49 installed horizontally and vertically, respectively, on the south face of the web of Sub-floorbeam 2 and 1 in below the web/flange cutout (between Rib 5 and Stringer 3) in Span 38 as the test trucks crossed in the northbound direction over the span in the crawl tests

Span 38, web of existing sub-floorbeams near web/flange cutout at sub-floorbeam-to-stringer connection							
Test name	Truck in lane	CH_50, (ksi)			CH_51, (ksi)		
		σ_{max}	σ_{min}	$\Delta\sigma$	σ_{max}	σ_{min}	$\Delta\sigma$
CRL1_36	Truck 1, (O.L)	1.2	-1.0	2.2	0.3	-0.7	1.0
	Truck 2, (O.L)	1.2	-0.9	2.1	0.3	-0.7	1.0
	Truck 3, (M.L)	1.1	-1.2	2.3	0.2	-1.4	1.6
	Truck 4, (M.L)	1.1	-1.2	2.3	0.2	-1.6	1.8
	Truck 5, (I.L)	1.0	0.0	1.0	0.2	-0.2	0.4
	Truck 6, (I.L)	1.0	0.0	1.0	0.2	-0.2	0.4
CRL2_36	Truck 1, (O.L)& Truck 2, (M.L)	2.6	-1.3	3.9	0.3	-2.3	2.6
	Truck 3, (OL)& Truck 4, (ML)	3.0	-1.3	4.3	0.3	-2.9	3.2
CRL3_36	Truck 5, (M.L)& Truck 6, (I.L)	1.9	-0.5	2.4	0.1	-1.4	1.5
	Truck 1, (ML)& Truck 2, (IL)	--	--	--	--	--	--
CRL4_36	Truck 3, (OL)& Truck 4, (ML) &Truck 5, (IL)	2.3	-2.0	4.3	0.2	-2.5	2.7
	Truck 6, (O.L)& Truck 1, (M.L) &Truck 2, (I.L)	2.7	-1.4	4.1	0.0	-2.3	2.3
M_36 (raw)	Multiple presence	2.1	-3.2	5.3	2.0	-0.5	2.5
M_36 (modified)	Multiple presence	3.9	-1.4	5.3	0.2	-2.3	2.6

Note:
"--" indicates significant noise in the data.

Table 5.35 – Summary of peak stresses (ksi) measured in strain gages CH_50 and CH_51 installed horizontally and vertically, respectively, on the north face of the web of Sub-floorbeam 2 and 1 in below the web/flange cutout (between Rib5 and Stringer 3) in Span 38 as the test trucks crossed in the northbound direction over the span in the crawl tests

5.3.11 Stresses in the Top and Bottom Flange of New Sub-floorbeam

As previously described, strain gages were installed on the top and bottom flange of the welded built-up new prototype sub-floorbeams installed in Span 36 and Span 45 at the sub-floorbeam-to-stringer connection.

In Span 36, strain gage CH_20 was installed on the top flange (T-section web) of the new intermediate Sub-floorbeam 8 west of the web of Stringer 3 and near the south end of the flange edge at 1 in from the toe of the weld used for attaching the web and the flange of the T-section and at 1 in from the edge of the reduced section of the flange. Strain gage CH_21 was also installed similar to strain gage CH_20 near the north end of the flange at 1 in from the toe of the weld used for attaching the web and the flange of the T-section and at 1 in from the edge of the reduced section of the flange. The strain gages on the east face of the stringer web were installed in a similar fashion to the gages installed on the west face of the stringer web. Strain gage CH_22 was installed near the south end of the flange, and strain gage CH_23 was installed near the north end of the flange. In addition, two strain gages, CH_24 and CH_25, were installed on the bottom cover plate bolted to the bottom flange of the same new Sub-floorbeam 8 at 1 in from the south and north edge of the cover plate, respectively.

In Span 45, strain gages were installed on the top flange of the new Sub-floorbeam 2, similar to those in Span 36. Specifically, strain gages CH_21, CH_22, CH_19, and CH_20 in Span 45 were installed on the new Sub-floorbeam 2 similar to strain gages CH_20, CH_21, CH_22, and CH_23, respectively.

The top flange welded detail can be classified as Category C detail per AASHTO Specifications, while the bottom flange bolted cover plate detail can be classified as Category B detail. The responses of strain gages CH_20 and CH_21 installed in Span 36 on the top flange of the new Sub-floorbeam 8 and strain gages CH_24 and CH_25 installed on the bottom flange of the same sub-floorbeam are shown in Figure 5.16 and Figure 5.17, respectively. As shown in the figures and as expected, tensile stresses were recorded by the gages installed on the top flange of the new sub-floorbeam and compressive stresses were recorded by the gages installed on the bottom flange of the same new-sub-floorbeam, indicating the sub-floorbeam is in negative bending.

Summaries of the maximum stress, minimum stress, and stress range values experienced by the gages in the crawl tests, including the multiple presence truck test are presented in Tables 5.36 through 5.40. The maximum stress ranges measured by strain gages CH_20, CH_21, CH_22, CH_23, CH_24, and CH_25 installed in Span 36 during the controlled crawl tests were 1.3 ksi, 1.3 ksi, 1.7 ksi, 1.2 ksi, 1.3 ksi, and 1.6 ksi, respectively. In Span 45, the maximum stress ranges measured by strain gages CH_21, CH_22, CH_19, and CH_20 during the controlled crawl tests were 1.0 ksi, 1.0 ksi, 1.1 ksi, and 2.0 ksi. All of the maximum measured stress range values are well below the CAFL of the detail.

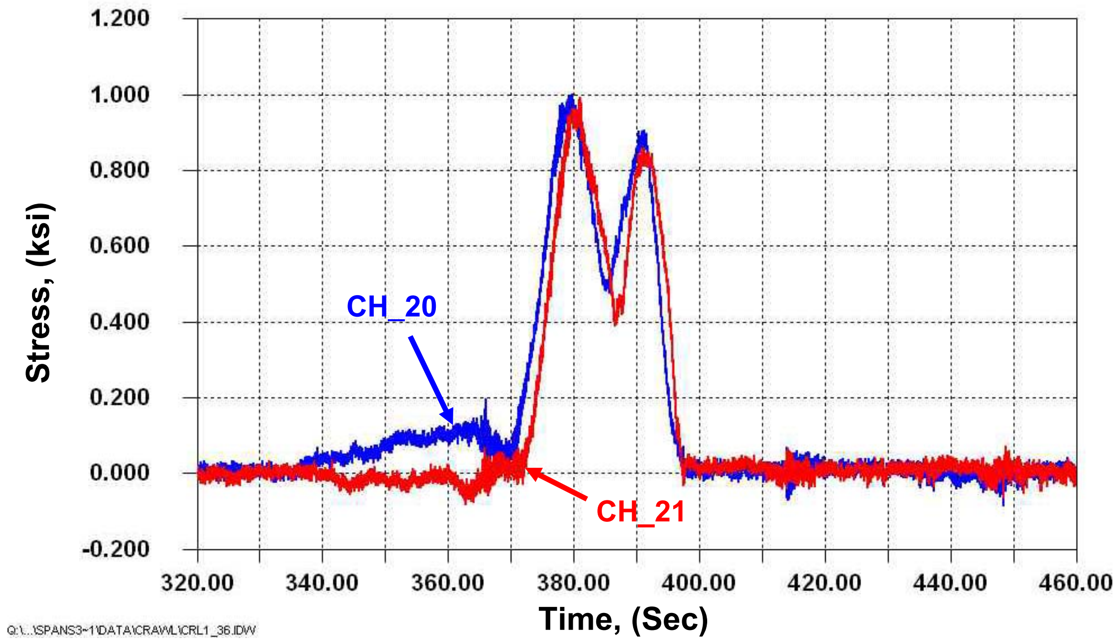


Figure 5.16 – Response of strain gages CH_20 and CH_21 installed on the top flange (T-section web) of the new Sub-floorbeam 8 west of the web of Stringer 3 and near the south and north end, respectively, of the flange edge at 1 in from the toe of the weld used for attaching the web and the flange of the T-section and at 1 in from the edge of the reduced section of the flange in Span 36 as Truck 2 crossed in the northbound direction over the span in the controlled load test CRL1_36

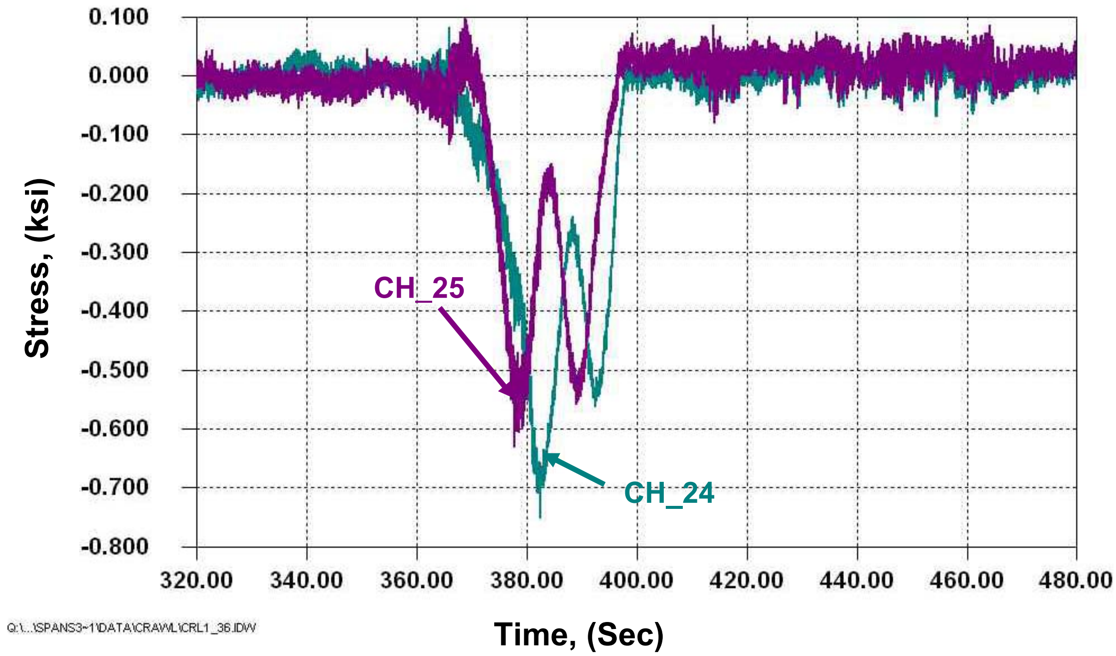


Figure 5.17 – Response of strain gages CH_24 and CH_25 installed on the bottom cover plate bolted to the bottom flange of new Sub-floorbeam 8 near the south and north edge, respectively, of the cover plate in Span 36 as Truck 2 crossed in the northbound direction over the span in the controlled load test CRL1_36

Span 36, top flange of the welded built-up new prototype Sub-floorbeam 8							
Test name	**Truck in lane**	**CH_20, (ksi)**			**CH_21, (ksi)**		
		σ_{max}	σ_{min}	$\Delta\sigma$	σ_{max}	σ_{min}	$\Delta\sigma$
CRL1_36	**Truck 1, (O.L)**	1.0	-0.3	1.3	0.9	-0.4	1.3
	Truck 2, (O.L)	1.0	0.0	1.0	1.0	-0.1	1.1
	Truck 3, (M.L)	0.6	0.0	0.6	0.3	0.0	0.3
	Truck 4, (M.L)	0.4	-0.3	0.7	0.3	-0.2	0.5
	Truck 5, (I.L)	0.1	-0.2	0.3	0.0	0.0	0.0
	Truck 6, (I.L)	0.1	-0.2	0.3	0.0	0.0	0.0
CRL2_36	**Truck 1, (O.L)& Truck 2, (M.L)**	1.1	-0.1	1.2	1.1	-0.2	1.3
	Truck 3, (OL)& Truck 4, (ML)	1.2	0.0	1.2	1.1	0.0	1.1
CRL3_36	**Truck 5, (M.L)& Truck 6, (I.L)**	0.4	-0.1	0.5	0.3	-0.1	0.4
	Truck 1, (ML)& Truck 2, (IL)	0.5	-0.2	0.7	0.2	-0.1	0.3
CRL4_36	**Truck 3, (OL)& Truck 4, (ML) &Truck 5, (IL)**	1.0	-0.1	1.1	1.1	-0.1	1.2
	Truck 6, (O.L)& Truck 1, (M.L) &Truck 2, (I.L)	1.3	0.0	1.3	1.2	0.0	1.2
M_36	**Multiple presence**	1.3	0.0	1.3	1.2	-0.1	1.3

Table 5.36 – Summary of peak stresses (ksi) measured in strain gages CH_20 and CH_21 installed on the top flange (T-section web) of the new Sub-floorbeam 8 west of the web of Stringer 3 and near the south and north end, respectively, of the flange edge at 1 in from the toe of the weld used for attaching the web and the flange of the T-section and at 1 in from the edge of the reduced section of the flange in Span 36 as the test trucks crossed in the northbound direction over the span in the crawl tests

Span 36, top flange of the welded built-up new prototype Sub-floorbeam 8							
Test name	Truck in lane	CH_22, (ksi)			CH_23, (ksi)		
		σ_{max}	σ_{min}	$\Delta\sigma$	σ_{max}	σ_{min}	$\Delta\sigma$
CRL1_36	Truck 1, (O.L)	0.5	-0.4	0.9	0.7	-0.1	0.8
	Truck 2, (O.L)	0.5	-0.4	0.9	0.7	-0.1	0.8
	Truck 3, (M.L)	0.9	0.0	0.9	0.3	0.0	0.3
	Truck 4, (M.L)	0.9	0.0	0.9	0.3	0.0	0.3
	Truck 5, (I.L)	0.2	0.0	0.2	0.0	-0.2	0.2
	Truck 6, (I.L)	0.2	0.0	0.2	0.0	-0.2	0.2
CRL2_36	Truck 1, (O.L)& Truck 2, (M.L)	1.2	-0.5	1.7	0.9	-0.3	1.2
	Truck 3, (OL)& Truck 4, (ML)	1.1	-0.4	1.5	0.9	-0.3	1.2
CRL3_36	Truck 5, (M.L)& Truck 6, (I.L)	0.9	-0.1	1.0	0.3	-0.1	0.4
	Truck 1, (ML)& Truck 2, (IL)	0.9	-0.1	1.0	0.5	0.0	0.5
CRL4_36	Truck 3, (OL)& Truck 4, (ML) &Truck 5, (IL)	1.2	-0.3	1.5	0.6	-0.2	0.8
	Truck 6, (O.L)& Truck 1, (M.L) &Truck 2, (I.L)	1.1	-0.2	1.3	1.1	0.0	1.1
M_36	Multiple presence	0.8	0.0	0.8	1.2	0.0	1.2

Table 5.37 – Summary of peak stresses (ksi) measured in strain gages CH_22 and CH_23 installed on the top flange (T-section web) of the new Sub-floorbeam 8 east of the web of Stringer 3 and near the south and north end, respectively, of the flange edge at 1 in from the toe of the weld used for attaching the web and the flange of the T-section and at 1 in from the edge of the reduced section of the flange in Span 36 as the test trucks crossed in the northbound direction over the span in the crawl tests

Span 36, bottom cover plate bolted to the bottom flange of the new Sub-floorbeam 8							
Test name	Truck in lane	CH_24, (ksi)			CH_25, (ksi)		
		σ_{max}	σ_{min}	$\Delta\sigma$	σ_{max}	σ_{min}	$\Delta\sigma$
CRL1_36	Truck 1, (O.L)	0.0	-0.7	0.7	0.1	-0.7	0.8
	Truck 2, (O.L)	0.0	-0.8	0.8	0.1	-0.6	0.7
	Truck 3, (M.L)	0.0	-0.2	0.2	0.1	-0.5	0.6
	Truck 4, (M.L)	0.0	-0.2	0.2	0.1	-0.6	0.7
	Truck 5, (I.L)	0.0	-0.3	0.3	0.0	-0.4	0.4
	Truck 6, (I.L)	0.0	-0.3	0.3	0.0	-0.3	0.3
CRL2_36	Truck 1, (O.L)& Truck 2, (M.L)	0.0	-0.9	0.9	0.0	-1.2	1.2
	Truck 3, (OL)& Truck 4, (ML)	0.0	-0.9	0.9	0.0	-1.1	1.1
CRL3_36	Truck 5, (M.L)& Truck 6, (I.L)	0.0	-0.5	0.5	0.0	-0.9	0.9
	Truck 1, (ML)& Truck 2, (IL)	0.0	-0.4	0.4	0.0	-0.9	0.9
CRL4_36	Truck 3, (OL)& Truck 4, (ML) &Truck 5, (IL)	0.0	-1.1	1.1	0.1	-1.4	1.5
	Truck 6, (O.L)& Truck 1, (M.L) &Truck 2, (I.L)	0.0	-1.1	1.1	0.1	-1.5	1.6
M_36	Multiple presence	0.1	-1.2	1.3	0.1	-1.2	1.3

Table 5.38 – Summary of peak stresses (ksi) measured in strain gages CH_24 and CH_25 bottom cover plate bolted to the bottom flange of new Sub-floorbeam 8 near the south and north edge, respectively, of the cover plate in Span 36 as the test trucks crossed in the northbound direction over the span in the crawl tests

Span 45, top flange of the welded built-up new prototype Sub-floorbeam 8							
Test name	Truck in lane	CH_21, (ksi)			CH_22, (ksi)		
		σ_{max}	σ_{min}	$\Delta\sigma$	σ_{max}	σ_{min}	$\Delta\sigma$
CRL1_45	Truck 1, (O.L)	0.5	0.0	0.5	0.0	0.4	0.4
	Truck 2, (O.L)	0.5	0.0	0.5	0.0	0.3	0.3
	Truck 3, (M.L)	0.4	0.0	0.4	0.6	-0.1	0.7
	Truck 4, (M.L)	0.4	0.0	0.4	0.5	-0.1	0.6
	Truck 5, (I.L)	0.0	-0.1	0.1	0.0	-0.1	0.1
	Truck 6, (I.L)	0.0	-0.1	0.1	0.0	-0.1	0.1
CRL2_45	Truck 1, (O.L)& Truck 2, (M.L)	0.9	-0.1	1.0	0.9	-0.1	1.0
	Truck 3, (OL)& Truck 4, (ML)	0.7	-0.1	0.8	0.9	0.0	0.9
CRL3_45	Truck 5, (M.L)& Truck 6, (I.L)	0.4	0.0	0.4	0.8	0.0	0.8
	Truck 1, (ML)& Truck 2, (IL)	0.4	0.0	0.4	0.6	0.0	0.6
[1]CRL4_45	Truck 3, (OL)& Truck 4, (ML) &Truck 5, (IL)	NA	NA	NA	NA	NA	NA
	Truck 6, (O.L)& Truck 1, (M.L) &Truck 2, (I.L)	NA	NA	NA	NA	NA	NA
M_45	Multiple presence	0.8	0.0	0.8	0.9	0.0	0.9

Note:
1. Data for this test were not retrieved

Table 5.39 – Summary of peak stresses (ksi) measured in strain gages CH_21 and CH_22 installed on the top flange (T-section web) of the new Sub-floorbeam 2 west of the web of Stringer 3 and near the south and north end, respectively, of the flange edge at 1 in from the toe of the weld used for attaching the web and the flange of the T-section and at 1 in from the edge of the reduced section of the flange in Span 45 as the test trucks crossed in the northbound direction over the span in the crawl tests

Span 45, top flange of the welded built-up new prototype Sub-floorbeam 8							
Test name	Truck in lane	CH_19, (ksi)			CH_20, (ksi)		
		σ_{max}	σ_{min}	$\Delta\sigma$	σ_{max}	σ_{min}	$\Delta\sigma$
CRL1_45	Truck 1, (O.L)	0.6	-0.2	0.8	1.1	-0.1	1.2
	Truck 2, (O.L)	0.5	-0.2	0.7	1.1	-0.1	1.2
	Truck 3, (M.L)	0.4	-0.1	0.5	0.9	-0.1	1.0
	Truck 4, (M.L)	0.4	-0.1	0.5	0.7	-0.1	0.8
	Truck 5, (I.L)	0.0	0.0	0.0	0.1	-0.1	0.2
	Truck 6, (I.L)	0.0	0.0	0.0	0.1	-0.1	0.2
CRL2_45	Truck 1, (O.L)& Truck 2, (M.L)	1.0	-0.1	1.1	1.9	-0.1	2.0
	Truck 3, (OL)& Truck 4, (ML)	0.6	-0.1	0.7	1.7	-0.1	1.8
CRL3_45	Truck 5, (M.L)& Truck 6, (I.L)	0.6	0.0	0.6	0.9	0.0	0.9
	Truck 1, (ML)& Truck 2, (IL)	0.4	-0.1	0.5	1.0	-0.1	1.1
[1]CRL4_45	Truck 3, (OL)& Truck 4, (ML) &Truck 5, (IL)	NA	NA	NA	NA	NA	NA
	Truck 6, (O.L)& Truck 1, (M.L) &Truck 2, (I.L)	NA	NA	NA	NA	NA	NA
M_45	Multiple presence	0.8	-0.1	0.9	1.8	0.0	1.8

Note:
1. Data for this test were not retrieved

Table 5.40 – Summary of peak stresses (ksi) measured in strain gages CH_19 and CH_20 installed on the top flange (T-section web) of the new Sub-floorbeam 2 east of the web of Stringer 3 and near the south and north end, respectively, of the flange edge at 1 in from the toe of the weld used for attaching the web and the flange of the T-section and at 1 in from the edge of the reduced section of the flange in Span 45 as the test trucks crossed in the northbound direction over the span in the crawl tests

5.3.12 Stresses in the Orthotropic Rib Web Plate

As discussed in Chapter 4.0, strain gages were installed on the orthotropic rib web plate near the connection of the rib bearing plates to the sub-floorbeam upper flange to measure the out-of-plane bending stresses in the web plate, if any.

In Span 35, strain gages were installed on the east and west web plate of Rib 6 at the connection to Sub-floorbeam 2. Specifically, strain gages CH_50 and CH_51 were installed on the west web plate of Rib 6 (south west and north west of the plate, respectively) at 2 in vertically from the bottom flange of the rib and approximately 4 1/2 in apart longitudinally (off of the centerline of the sub-floorbeam flange). On the east web plate of the same rib, strain gages CH_52 and CH_53 were installed on the south east and north east of the plate, respectively at 2 in vertically from the bottom flange of the rib and approximately 4 1/2 in apart longitudinally (off of the centerline of the sub-floorbeam flange), where strain gage CH_52 was installed directly across from strain gage CH_50, and strain gage CH_53 was installed directly across from strain gage CH_51.

Similarly, in Span 36, strain gages were installed on the east and west web plate of Rib 6 at the connection to Sub-floorbeam, where strain gages CH_28, CH_30, CH_29, and CH_31 were installed on Span 36 in locations similar to strain gages CH_50, CH_51, CH_52, and CH_53 installed in Span 35.

In Span 38, strain gages were also installed on the east and west web plate of Rib 6 at the connection to Sub-floorbeam 2, where strain gages CH_55, CH_56, CH_58, and CH_57 were installed in Span 38 in locations similar to strain gages CH_50, CH_51, CH_52, and CH_53 installed in Span 35.

In Span 45, strain gages were also installed on the east and west web plate of Rib 6 at the connection to Sub-floorbeam 2, where strain gages CH_25, CH_27, CH_26, and CH_28 were installed in Span 45 in locations similar to strain gages CH_50, CH_51, CH_52, and CH_53 installed in Span 35.

Figure 5.18 shows the response of strain gages CH_28, CH_30, CH_29, and CH_31 installed in Span 36 on the east and west web plate of Rib 6 during the crossing of Truck 1 in the outside lane over the span in the crawl test CRL1_36. The figure shows small difference in the response in all four gages with slightly higher response measured by strain gage CH_30. The response in the gages increased as the test truck crossed directly over the gages. This can be seen in Figure 5.19, which shows the response of all four gages to the crossing of Truck 4 in the middle lane during crawl test CRL1_36. Figure 5.20 shows the response CH_50, CH_52, CH_51, and CH_53 installed in Span 35 on the east and west web plate of Rib 6 as mentioned above during the crossing of Truck 4 in the middle lane over the span in the crawl test CRL1_34. A comparison between the response of the strain gages installed in Span 35 and those installed in Span 36 in comparable locations show that the retrofit scheme installed in Span 36 at the instrumented location (i.e., installation of keeper blocks, etc.) could have resulted in a decreased magnitude of the stress range measured by strain gages CH_29 and CH_31 compared to strain gages CH_52 and CH_53, respectively, installed in Span 35. On the other hand, the figure also shows an increase in the magnitude of the stress range measured by strain gages CH_28 and CH_30 installed in Span 36 compared to strain gages CH_50 and CH_51, respectively, installed in Span 35, which could be caused by the retrofit. It is important to note that the increase in the stress cycle may result in fatigue crack growth from the weld root, instead of the weld toe, considering the residual stresses in the weld and the increased stress on the weld throat.

Summaries of the maximum stress, minimum stress, and stress range values experienced by the gages in the crawl tests, including the multiple presence truck test are presented in Tables 5.41 through 5.48.

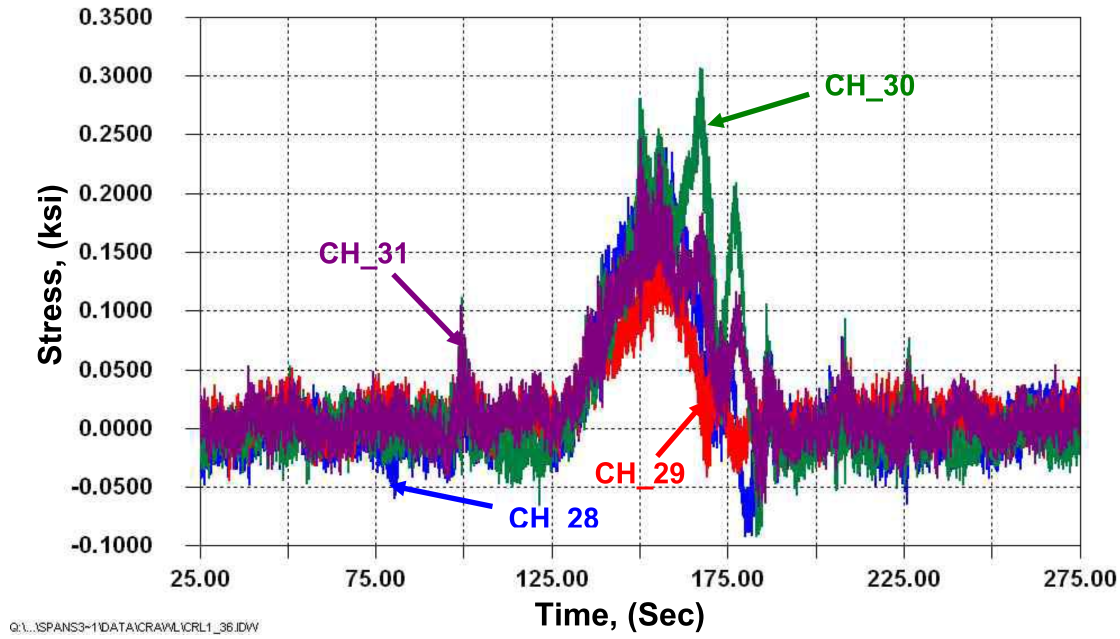


Figure 5.18 – Response of strain gages CH_28, CH_29, CH_30, and CH_31 installed in Span 36 on the east and west web plate of Rib 6 as Truck 1 crossed in the northbound direction over the span in the outside lane during the controlled load test CRL1_36

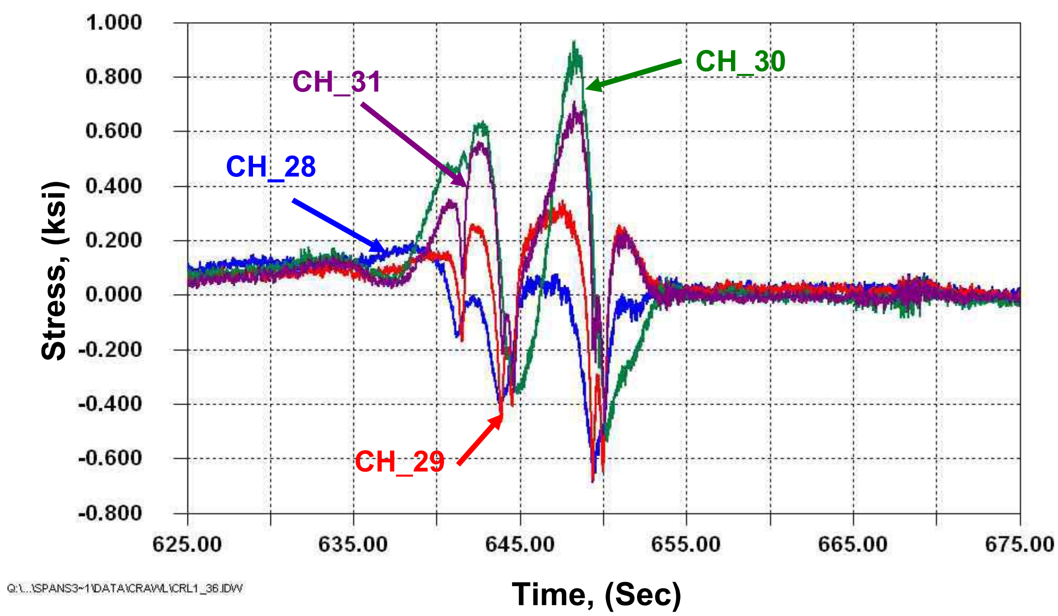


Figure 5.19 – Response of strain gages CH_28, CH_29, CH_30, and CH_31 installed in Span 36 on the east and west web plate of Rib 6 as Truck 4 crossed in the northbound direction over the span in the middle lane during the controlled load test CRL1_36

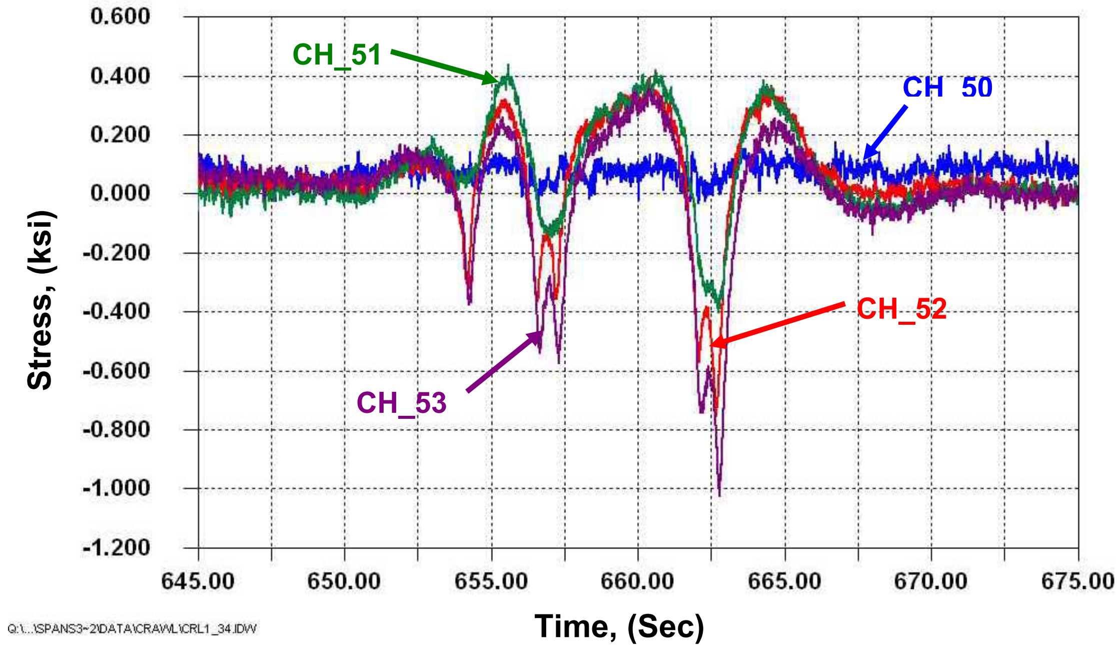


Figure 5.20 – Response of strain gages CH_50, CH_51, CH_52, and CH_53 installed in Span 35 on the east and west web plate of Rib 6 as Truck 4 crossed in the northbound direction over the span in the middle lane during the controlled load test CRL1_34

Span 35, west web plate of Rib 6							
Test name	Truck in lane	CH_50, (ksi)			CH_51, (ksi)		
		σ_{max}	σ_{min}	$\Delta\sigma$	σ_{max}	σ_{min}	$\Delta\sigma$
CRL1_34	Truck 1, (O.L)	0.0	0.0	0.0	0.0	0.0	0.0
	Truck 2, (O.L)	0.0	0.0	0.0	0.0	0.0	0.0
	Truck 3, (M.L)	0.0	0.0	0.0	0.4	-0.2	0.6
	Truck 4, (M.L)	0.0	0.0	0.0	0.4	-0.4	0.8
	Truck 5, (I.L)	0.0	0.0	0.0	0.0	0.0	0.0
	Truck 6, (I.L)	0.0	0.0	0.0	0.0	0.0	0.0
CRL2_34	Truck 1, (O.L)& Truck 2, (M.L)	0.2	0.0	0.2	0.5	-0.3	0.8
	Truck 3, (OL)& Truck 4, (ML)	0.1	0.0	0.1	0.4	-0.5	0.9
CRL3_34	Truck 5, (M.L)& Truck 6, (I.L)	0.0	0.0	0.0	0.6	-0.5	1.1
	Truck 1, (ML)& Truck 2, (IL)	0.0	0.0	0.0	0.2	-0.3	0.5
CRL4_34	Truck 3, (OL)& Truck 4, (ML) &Truck 5, (IL)	0.0	0.0	0.0	0.4	-0.3	0.7
	Truck 6, (O.L)& Truck 1, (M.L) &Truck 2, (I.L)	0.1	0.0	0.1	0.4	-0.3	0.7
M_34	Multiple presence	0.3	0.0	0.3	0.4	-0.2	0.6

Table 5.41 – Summary of peak stresses (ksi) measured in strain gages CH_50 and CH_51 installed on the west web plate of Rib 6 (south west and north west of the plate, respectively) at 2 in vertically from the bottom flange of the rib and approximately 4 1/2 in apart longitudinally (off of the centerline of the sub-floorbeam flange) in Span 35 as the test trucks crossed in the northbound direction over the span in the crawl tests

Span 35, east web plate of Rib 6							
Test name	Truck in lane	CH_52, (ksi)			CH_53, (ksi)		
		σ_{max}	σ_{min}	$\Delta\sigma$	σ_{max}	σ_{min}	$\Delta\sigma$
CRL1_34	Truck 1, (O.L)	0.0	0.0	0.0	0.0	0.0	0.0
	Truck 2, (O.L)	0.0	0.0	0.0	0.0	0.0	0.0
	Truck 3, (M.L)	0.3	-0.6	0.9	0.4	-0.6	1.0
	Truck 4, (M.L)	0.4	-0.7	1.1	0.4	-1.0	1.4
	Truck 5, (I.L)	0.0	0.0	0.0	0.0	0.0	0.0
	Truck 6, (I.L)	0.0	0.0	0.0	0.0	0.0	0.0
CRL2_34	Truck 1, (O.L)& Truck 2, (M.L)	0.4	-0.7	1.4	0.3	-0.9	1.2
	Truck 3, (OL)& Truck 4, (ML)	0.3	-0.8	1.1	0.3	-1.1	1.4
CRL3_34	Truck 5, (M.L)& Truck 6, (I.L)	0.6	-0.7	1.3	0.5	-1.0	1.5
	Truck 1, (ML)& Truck 2, (IL)	0.3	-0.3	0.6	0.2	-0.4	0.6
CRL4_34	Truck 3, (OL)& Truck 4, (ML) &Truck 5, (IL)	0.3	-0.7	1.0	0.5	-1.1	1.6
	Truck 6, (O.L)& Truck 1, (M.L) &Truck 2, (I.L)	0.3	-0.7	1.0	0.3	-0.9	1.2
M_34	Multiple presence	0.4	-0.2	0.6	0.2	-0.3	0.5

Table 5.42 – Summary of peak stresses (ksi) measured in strain gages CH_52 and CH_53 installed on the east web plate of Rib 6 (south east and north east of the plate, respectively) at 2 in vertically from the bottom flange of the rib and approximately 4 1/2 in apart longitudinally (off of the centerline of the sub-floorbeam flange) in Span 35 as the test trucks crossed in the northbound direction over the span in the crawl tests

Span 36, west web plate of Rib 6							
Test name	Truck in lane	CH_28, (ksi)			CH_30, (ksi)		
		σ_{max}	σ_{min}	$\Delta\sigma$	σ_{max}	σ_{min}	$\Delta\sigma$
CRL1_36	Truck 1, (O.L)	0.3	-0.1	0.4	0.3	-0.1	0.4
	Truck 2, (O.L)	0.3	-0.1	0.4	0.3	0.0	0.3
	Truck 3, (M.L)	0.1	-0.5	0.6	1.0	-0.5	1.5
	Truck 4, (M.L)	0.1	-0.7	0.8	1.0	-0.5	1.5
	Truck 5, (I.L)	0.2	-0.2	0.4	0.2	0.0	0.2
	Truck 6, (I.L)	0.2	-0.1	0.3	0.2	-0.1	0.3
CRL2_36	Truck 1, (O.L)& Truck 2, (M.L)	--	--	--	0.9	-0.5	1.4
	Truck 3, (OL)& Truck 4, (ML)	--	--	--	1.0	-0.1	1.1
CRL3_36	Truck 5, (M.L)& Truck 6, (I.L)	0.0	-0.8	0.8	0.9	-0.5	1.4
	Truck 1, (ML)& Truck 2, (IL)	0.3	-0.4	0.7	0.7	-0.4	1.1
CRL4_36	Truck 3, (OL)& Truck 4, (ML) &Truck 5, (IL)	0.0	-0.9	0.9	1.0	-0.9	1.9
	Truck 6, (O.L)& Truck 1, (M.L) &Truck 2, (I.L)	0.6	-0.6	1.2	1.1	-0.3	1.4
M_36	Multiple presence	--	--	--	0.8	-0.3	1.1

Note:
"--" indicates significant noise in the data.

Table 5.43 – Summary of peak stresses (ksi) measured in strain gages CH_28 and CH_30 installed on the west web plate of Rib 6 (south west and north west of the plate, respectively) at 2 in vertically from the bottom flange of the rib and approximately 4 1/2 in apart longitudinally (off of the centerline of the sub-floorbeam flange) in Span 36 as the test trucks crossed in the northbound direction over the span in the crawl tests

Span 36, east web plate of Rib 6							
Test name	Truck in lane	CH_29, (ksi)			CH_31, (ksi)		
		σ_{max}	σ_{min}	$\Delta\sigma$	σ_{max}	σ_{min}	$\Delta\sigma$
CRL1_36	Truck 1, (O.L)	0.2	0.0	0.2	0.2	0.0	0.2
	Truck 2, (O.L)	0.2	0.0	0.2	0.2	0.0	0.2
	Truck 3, (M.L)	0.3	-0.6	0.9	0.6	-0.4	1.0
	Truck 4, (M.L)	0.3	-0.7	1.0	0.7	-0.5	1.2
	Truck 5, (I.L)	0.1	0.0	0.1	0.1	0.0	0.1
	Truck 6, (I.L)	0.1	0.0	0.1	0.1	0.0	0.1
CRL2_36	Truck 1, (O.L)& Truck 2, (M.L)	0.3	-0.6	0.9	0.8	-0.2	1.0
	Truck 3, (OL)& Truck 4, (ML)	0.4	-0.7	1.1	0.9	-0.4	1.3
CRL3_36	Truck 5, (M.L)& Truck 6, (I.L)	0.4	-0.7	1.1	0.9	-0.3	1.2
	Truck 1, (ML)& Truck 2, (IL)	0.3	-0.4	0.7	0.6	-0.1	0.7
CRL4_36	Truck 3, (OL)& Truck 4, (ML) &Truck 5, (IL)	0.4	-0.6	1.0	0.9	-0.4	1.3
	Truck 6, (O.L)& Truck 1, (M.L) &Truck 2, (I.L)	0.4	-0.6	1.0	0.9	-0.1	1.0
M_36	Multiple presence	0.4	0.0	0.4	0.9	-0.1	1.0

Table 5.44 – Summary of peak stresses (ksi) measured in strain gages CH_29 and CH_31 installed on the east web plate of Rib 6 (south east and north east of the plate, respectively) at 2 in vertically from the bottom flange of the rib and approximately 4 1/2 in apart longitudinally (off of the centerline of the sub-floorbeam flange) in Span 36 as the test trucks crossed in the northbound direction over the span in the crawl tests

Span 38, west web plate of Rib 6							
Test name	Truck in lane	CH_55, (ksi)			CH_56, (ksi)		
		σ_{max}	σ_{min}	$\Delta\sigma$	σ_{max}	σ_{min}	$\Delta\sigma$
CRL1_36	Truck 1, (O.L)	0.0	0.0	0.0	0.0	0.0	0.0
	Truck 2, (O.L)	0.0	0.0	0.0	0.0	0.0	0.0
	Truck 3, (M.L)	0.3	-0.3	0.6	0.4	-0.3	0.7
	Truck 4, (M.L)	0.3	-0.4	0.7	0.4	-0.4	0.8
	Truck 5, (I.L)	0.0	0.0	0.0	0.0	0.0	0.0
	Truck 6, (I.L)	0.0	0.0	0.0	0.0	0.0	0.0
CRL2_36	Truck 1, (O.L)& Truck 2, (M.L)	0.4	-0.2	0.6	0.7	-0.2	0.9
	Truck 3, (OL)& Truck 4, (ML)	0.2	-1.3	1.5	0.3	-1.2	1.5
CRL3_36	Truck 5, (M.L)& Truck 6, (I.L)	0.3	-0.4	0.7	0.5	-0.4	0.9
	Truck 1, (ML)& Truck 2, (IL)	0.0	-0.2	0.2	0.0	-0.2	0.2
CRL4_36	Truck 3, (OL)& Truck 4, (ML) &Truck 5, (IL)	0.3	-0.7	1.0	0.3	-0.7	1.0
	Truck 6, (O.L)& Truck 1, (M.L) &Truck 2, (I.L)	0.4	-0.6	1.0	0.4	-0.5	0.9
M_36 (raw)	Multiple presence	0.4	-0.3	0.7	0.6	-0.3	0.9
M_36 (modified)	Multiple presence	0.3	-0.4	0.7	0.3	-0.6	0.9

Note:
"--" indicates significant noise in the data.

Table 5.45 – Summary of peak stresses (ksi) measured in strain gages CH_55 and CH_56 installed on the west web plate of Rib 6 (south west and north west of the plate, respectively) at 2 in vertically from the bottom flange of the rib and approximately 4 1/2 in apart longitudinally (off of the centerline of the sub-floorbeam flange) in Span 38 as the test trucks crossed in the northbound direction over the span in the crawl tests

Span 38, east web plate of Rib 6							
Test name	Truck in lane	CH_58, (ksi)			CH_57, (ksi)		
		σ_{max}	σ_{min}	$\Delta\sigma$	σ_{max}	σ_{min}	$\Delta\sigma$
CRL1_36	Truck 1, (O.L)	0.0	-0.1	0.1	0.0	-0.1	0.1
	Truck 2, (O.L)	0.0	-0.1	0.1	0.0	-0.1	0.1
	Truck 3, (M.L)	0.3	-0.8	1.1	0.4	-0.3	0.7
	Truck 4, (M.L)	0.3	-0.9	1.2	0.4	-0.4	0.8
	Truck 5, (I.L)	0.0	0.0	0.0	0.0	-0.1	0.1
	Truck 6, (I.L)	0.0	0.0	0.0	0.0	-0.1	0.1
CRL2_36	Truck 1, (O.L)& Truck 2, (M.L)	0.1	-0.9	1.0	0.3	-0.5	0.8
	Truck 3, (OL)& Truck 4, (ML)	0.5	-0.8	1.3	0.2	-1.1	1.3
CRL3_36	Truck 5, (M.L)& Truck 6, (I.L)	0.3	-0.7	1.0	0.5	-0.4	0.9
	Truck 1, (ML)& Truck 2, (IL)	0.0	0.0	0.0	0.0	-0.2	0.2
CRL4_36	Truck 3, (OL)& Truck 4, (ML) &Truck 5, (IL)	0.3	-1.1	1.4	0.3	-0.7	1.0
	Truck 6, (O.L)& Truck 1, (M.L) &Truck 2, (I.L)	0.3	-0.8	1.1	0.4	-0.5	0.9
M_36	Multiple presence	--	--	--	--	--	--

Note:
"--" indicates significant noise in the data.

Table 5.46 – Summary of peak stresses (ksi) measured in strain gages CH_58 and CH_57 installed on the east web plate of Rib 6 (south east and north east of the plate, respectively) at 2 in vertically from the bottom flange of the rib and approximately 4 1/2 in apart longitudinally (off of the centerline of the sub-floorbeam flange) in Span 38 as the test trucks crossed in the northbound direction over the span in the crawl tests

Span 45, west web plate of Rib 6							
Test name	Truck in lane	CH_25, (ksi)			CH_27, (ksi)		
		σ_{max}	σ_{min}	$\Delta\sigma$	σ_{max}	σ_{min}	$\Delta\sigma$
CRL1_45	Truck 1, (O.L)	0.3	-0.1	0.4	0.1	0.0	0.1
	Truck 2, (O.L)	0.3	-0.1	0.4	0.1	0.0	0.1
	Truck 3, (M.L)	0.5	-0.3	0.8	0.2	-0.3	0.5
	Truck 4, (M.L)	0.4	-0.8	1.2	0.1	-0.7	0.8
	Truck 5, (I.L)	0.1	-0.1	0.2	0.1	-0.1	0.2
	Truck 6, (I.L)	0.1	-0.1	0.2	0.1	-0.1	0.2
CRL2_45	Truck 1, (O.L)& Truck 2, (M.L)	0.8	-0.5	1.3	0.2	-0.5	0.7
	Truck 3, (OL)& Truck 4, (ML)	0.7	-0.7	1.4	0.2	-0.7	0.9
CRL3_45	Truck 5, (M.L)& Truck 6, (I.L)	0.6	-0.2	0.8	0.2	-0.4	0.6
	Truck 1, (ML)& Truck 2, (IL)	0.5	-0.4	0.9	0.2	-0.3	0.5
[1]CRL4_45	Truck 3, (OL)& Truck 4, (ML) &Truck 5, (IL)	NA	NA	NA	NA	NA	NA
	Truck 6, (O.L)& Truck 1, (M.L) &Truck 2, (I.L)	NA	NA	NA	NA	NA	NA
M_45	Multiple presence	0.8	-0.1	0.9	0.3	-0.3	0.6

Note:
1. Data for this test were not retrieved

Table 5.47 – Summary of peak stresses (ksi) measured in strain gages CH_25 and CH_27 installed on the west web plate of Rib 6 (south west and north west of the plate, respectively) at 2 in vertically from the bottom flange of the rib and approximately 4 1/2 in apart longitudinally (off of the centerline of the sub-floorbeam flange) in span 45 as the test trucks crossed in the northbound direction over the span in the crawl tests

Span 45, east web plate of Rib 6							
Test name	Truck in lane	CH_26, (ksi)			CH_28, (ksi)		
		σ_{max}	σ_{min}	$\Delta\sigma$	σ_{max}	σ_{min}	$\Delta\sigma$
CRL1_45	Truck 1, (O.L)	0.2	0.0	0.2	0.1	-0.2	0.3
	Truck 2, (O.L)	0.2	0.0	0.2	0.1	-0.2	0.3
	Truck 3, (M.L)	0.4	-0.7	1.1	0.3	-1.1	1.4
	Truck 4, (M.L)	0.5	-1.1	1.6	0.4	-1.4	1.8
	Truck 5, (I.L)	0.1	0.0	0.1	0.0	0.0	0.0
	Truck 6, (I.L)	0.1	0.0	0.1	0.0	0.0	0.0
CRL2_45	Truck 1, (O.L)& Truck 2, (M.L)	0.6	-1.1	1.7	0.3	-1.5	1.8
	Truck 3, (OL)& Truck 4, (ML)	0.6	-0.9	1.5	0.3	-1.6	1.9
CRL3_45	Truck 5, (M.L)& Truck 6, (I.L)	0.7	-0.4	1.1	0.3	-1.0	1.3
	Truck 1, (ML)& Truck 2, (IL)	0.6	0.0	0.6	0.4	-0.5	0.9
[1]CRL4_45	Truck 3, (OL)& Truck 4, (ML) &Truck 5, (IL)	NA	NA	NA	NA	NA	NA
	Truck 6, (O.L)& Truck 1, (M.L) &Truck 2, (I.L)	NA	NA	NA	NA	NA	NA
M_45	Multiple presence	0.8	-0.5	1.3	0.3	-1.2	1.5

Note:
1. Data for this test were not retrieved

Table 5.46 – Summary of peak stresses (ksi) measured in strain gages CH_26 and CH_28 installed on the east web plate of Rib 6 (south east and north east of the plate, respectively) at 2 in vertically from the bottom flange of the rib and approximately 4 1/2 in apart longitudinally (off of the centerline of the sub-floorbeam flange) in Span 45 as the test trucks crossed in the northbound direction over the span in the crawl tests

5.3.13 Longitudinal Displacement between the Main Girder and the Deck

Span 34, longitudinal displacement between the main girder and the deck plate					
Test name	Truck in lane	CH_1, (inches)		CH_30, (inches)	
		δ_{max}	δ_{min}	δ_{max}	δ_{min}
CRL1_34	Truck 1, (O.L)	0.005	0.000	0.006	-0.001
	Truck 2, (O.L)	0.005	-0.001	0.005	-0.001
	Truck 3, (M.L)	0.003	-0.001	0.004	-0.001
	Truck 4, (M.L)	0.004	0.000	0.005	-0.001
	Truck 5, (I.L)	0.003	0.000	0.003	-0.001
	Truck 6, (I.L)	0.003	0.000	0.003	-0.002
CRL2_34	Truck 1, (O.L)& Truck 2, (M.L)	0.009	0.000	0.010	-0.001
	Truck 3, (OL)& Truck 4, (ML)	0.008	-0.001	0.009	-0.001
CRL3_34	Truck 5, (M.L)& Truck 6, (I.L)	0.006	-0.001	0.009	-0.001
	Truck 1, (ML)& Truck 2, (IL)	0.006	-0.001	0.008	-0.001
CRL4_34	Truck 3, (OL)& Truck 4, (ML) &Truck 5, (IL)	0.010	-0.001	0.013	-0.001
	Truck 6, (O.L)& Truck 1, (M.L) &Truck 2, (I.L)	0.011	-0.001	0.012	-0.001
M_34	Multiple presence	0.012	0.000	0.013	0.000

Table 5.47 – Summary of peak measured displacements (inches) measured in displacement sensors CH_1 and CH_30 installed to measure the displacement between the main girder and the deck plate in Span 34

Span 35, longitudinal displacement between the main girder and the deck plate					
Test name	Truck in lane	CH_31, (inches)		CH_57, (inches)	
		δ_{max}	δ_{min}	δ_{max}	δ_{min}
CRL1_34	Truck 1, (O.L)	0.042	-0.002	0.008	-0.001
	Truck 2, (O.L)	0.052	-0.006	0.008	-0.001
	Truck 3, (M.L)	0.046	-0.001	0.007	0.000
	Truck 4, (M.L)	0.043	-0.001	0.006	0.000
	Truck 5, (I.L)	0.031	-0.006	0.004	0.000
	Truck 6, (I.L)	0.035	-0.001	0.004	0.000
CRL2_34	Truck 1, (O.L)& Truck 2, (M.L)	0.071	-0.005	0.015	-0.001
	Truck 3, (OL)& Truck 4, (ML)	0.063	0.000	0.014	-0.001
CRL3_34	Truck 5, (M.L)& Truck 6, (I.L)	0.063	0.000	0.013	-0.001
	Truck 1, (ML)& Truck 2, (IL)	0.060	-0.002	0.012	-0.002
CRL4_34	Truck 3, (OL)& Truck 4, (ML) &Truck 5, (IL)	0.121	0.000	0.023	0.000
	Truck 6, (O.L)& Truck 1, (M.L) &Truck 2, (I.L)	0.128	0.000	0.023	-0.001
M_34	Multiple presence	0.125	0.000	0.021	0.000

Table 5.48 – Summary of peak measured displacements (inches) measured in displacement sensors CH_31 and CH_57 installed to measure the displacement between the main girder and the deck plate in Span 35

Span 36, longitudinal displacement between the main girder and the deck plate					
Test name	Truck in lane	CH_1, (inches)		CH_36, (inches)	
		δ_{max}	δ_{min}	δ_{max}	δ_{min}
CRL1_36	Truck 1, (O.L)	0.004	0.000	0.001	-0.002
	Truck 2, (O.L)	0.004	0.000	0.001	-0.002
	Truck 3, (M.L)	0.003	0.000	0.001	-0.001
	Truck 4, (M.L)	0.003	0.000	0.001	-0.001
	Truck 5, (I.L)	0.003	0.000	0.000	-0.001
	Truck 6, (I.L)	0.003	0.000	0.000	-0.001
CRL2_36	Truck 1, (O.L)& Truck 2, (M.L)	0.008	-0.002	0.002	-0.004
	Truck 3, (OL)& Truck 4, (ML)	0.008	-0.001	0.001	-0.005
CRL3_36	Truck 5, (M.L)& Truck 6, (I.L)	0.005	0.000	0.001	-0.002
	Truck 1, (ML)& Truck 2, (IL)	0.005	0.000	0.001	-0.002
CRL4_36	Truck 3, (OL)& Truck 4, (ML) &Truck 5, (IL)	0.009	0.000	0.002	-0.004
	Truck 6, (O.L)& Truck 1, (M.L) &Truck 2, (I.L)	0.011	0.000	0.002	-0.004
M_36	Multiple presence	0.011	0.000	0.001	-0.004

Table 5.49 – Summary of peak measured displacements (inches) in displacement sensors CH_1 and CH_36 installed to measure the displacement between the main girder and the deck plate in Span 36

Span 38, longitudinal displacement between the main girder and the deck plate					
Test name	Truck in lane	CH_39, (inches)		CH_62, (inches)	
		δ_{max}	δ_{min}	δ_{max}	δ_{min}
CRL1_36	Truck 1, (O.L)	0.003	-0.061	0.004	-0.062
	Truck 2, (O.L)	0.003	-0.060	0.001	-0.059
	Truck 3, (M.L)	0.003	-0.047	0.003	-0.047
	Truck 4, (M.L)	0.003	-0.044	0.003	-0.045
	Truck 5, (I.L)	0.000	-0.035	0.003	-0.037
	Truck 6, (I.L)	0.000	-0.037	0.004	-0.039
CRL2_36	Truck 1, (O.L)& Truck 2, (M.L)	0.008	-0.103	0.010	-0.106
	Truck 3, (OL)& Truck 4, (ML)	0.010	-0.089	0.008	-0.095
CRL3_36	Truck 5, (M.L)& Truck 6, (I.L)	0.007	-0.085	0.007	-0.094
	Truck 1, (ML)& Truck 2, (IL)	0.002	-0.067	0.003	-0.089
CRL4_36	Truck 3, (OL)& Truck 4, (ML) &Truck 5, (IL)	0.010	-0.132	0.008	-0.138
	Truck 6, (O.L)& Truck 1, (M.L) &Truck 2, (I.L)	0.009	-0.139	0.006	-0.147
M_36 (raw)	Multiple presence	0.124	-0.028	0.005	-0.156
M_36 (modified)	Multiple presence	0.009	-0.143	0.005	-0.156

Table 5.50 – Summary of peak measured displacements (inches) measured in displacement sensors CH_39 and CH_62 installed to measure the displacement between the main girder and the deck plate in Span 38

Span 45, longitudinal displacement between the main girder and the deck plate					
Test name	Truck in lane	CH_1, (inches)		CH_40, (inches)	
		δ_{max}	δ_{min}	δ_{max}	δ_{min}
CRL1_45	Truck 1, (O.L)	0.007	0.000	0.005	0.000
	Truck 2, (O.L)	0.006	0.000	0.006	0.000
	Truck 3, (M.L)	0.005	0.000	0.004	0.000
	Truck 4, (M.L)	0.004	0.000	0.004	0.000
	Truck 5, (I.L)	0.003	0.000	0.003	0.000
	Truck 6, (I.L)	0.003	0.000	0.003	0.000
CRL2_45	Truck 1, (O.L)& Truck 2, (M.L)	0.012	0.000	0.010	0.000
	Truck 3, (OL)& Truck 4, (ML)	0.011	0.000	0.009	0.000
CRL3_45	Truck 5, (M.L)& Truck 6, (I.L)	0.009	0.000	0.008	0.000
	Truck 1, (ML)& Truck 2, (IL)	0.009	0.000	0.008	0.000
[1]CRL4_45	Truck 3, (OL)& Truck 4, (ML) &Truck 5, (IL)	NA	NA	NA	NA
	Truck 6, (O.L)& Truck 1, (M.L) &Truck 2, (I.L)	NA	NA	NA	NA
M_45	Multiple presence	0.015	0.001	0.015	0.001

Note:
1. Data for this test were not retrieved

Table 5.51 – Summary of peak measured displacements (inches) measured in displacement sensors CH_1 and CH_40 installed to measure the displacement between the main girder and the deck plate in Span 45

5.3.14 Displacement at New and Existing Sub-floorbeam-to-Stringer Connection

Span 34, displacement at existing sub-floorbeam-to-stringer connection			
Test name	**Truck in lane**	**CH_17, (inches)**	
		δ_{max}	δ_{min}
CRL1_34	**Truck 1, (O.L)**	--	--
	Truck 2, (O.L)	--	--
	Truck 3, (M.L)	--	--
	Truck 4, (M.L)	--	--
	Truck 5, (I.L)	--	--
	Truck 6, (I.L)	--	--
CRL2_34	**Truck 1, (O.L)& Truck 2, (M.L)**	--	--
	Truck 3, (OL)& Truck 4, (ML)	--	--
CRL3_34	**Truck 5, (M.L)& Truck 6, (I.L)**	--	--
	Truck 1, (ML)& Truck 2, (IL)	--	--
CRL4_34	**Truck 3, (OL)& Truck 4, (ML) &Truck 5, (IL)**	--	--
	Truck 6, (O.L)& Truck 1, (M.L) &Truck 2, (I.L)	--	--
M_34	**Multiple presence**	--	--

Note:
"--" indicates significant noise in the data.

Table 5.52 – Summary of peak measured displacements (inches) measured in displacement sensor CH_17 installed on Span 34 to measure the displacement at existing sub-floorbeam-to-stringer connection

Span 35, displacement at existing sub-floorbeam-to-stringer connection			
Test name	**Truck in lane**	**CH_43, (inches)**	
		δ_{max}	δ_{min}
CRL1_34	**Truck 1, (O.L)**	0.001	-0.001
	Truck 2, (O.L)	0.001	0.000
	Truck 3, (M.L)	0.001	0.000
	Truck 4, (M.L)	0.000	-0.001
	Truck 5, (I.L)	-0.001	-0.002
	Truck 6, (I.L)	0.000	-0.001
CRL2_34	**Truck 1, (O.L)& Truck 2, (M.L)**	0.001	0.000
	Truck 3, (OL)& Truck 4, (ML)	0.001	0.000
CRL3_34	**Truck 5, (M.L)& Truck 6, (I.L)**	0.000	-0.001
	Truck 1, (ML)& Truck 2, (IL)	0.000	-0.001
CRL4_34	**Truck 3, (OL)& Truck 4, (ML) &Truck 5, (IL)**	0.007	-0.001
	Truck 6, (O.L)& Truck 1, (M.L) &Truck 2, (I.L)	0.003	-0.003
M_34	**Multiple presence**	--	--

Note:
“--“ indicates significant noise in the data.

Table 5.53 – Summary of peak measured displacements (inches) measured in displacement sensor CH_43 installed on Span 35 to measure the displacement at existing sub-floorbeam-to-stringer connection

Span 36, displacement at new sub-floorbeam-to-stringer connection			
Test name	**Truck in lane**	**CH_19, (inches)**	
		δ_{max}	δ_{min}
CRL1_36	**Truck 1, (O.L)**	0.000	0.000
	Truck 2, (O.L)	0.000	0.000
	Truck 3, (M.L)	0.000	0.000
	Truck 4, (M.L)	0.000	0.000
	Truck 5, (I.L)	0.000	0.000
	Truck 6, (I.L)	0.000	0.000
CRL2_36	**Truck 1, (O.L)& Truck 2, (M.L)**	0.000	-0.003
	Truck 3, (OL)& Truck 4, (ML)	0.001	-0.002
CRL3_36	**Truck 5, (M.L)& Truck 6, (I.L)**	0.000	0.000
	Truck 1, (ML)& Truck 2, (IL)	0.000	0.000
CRL4_36	**Truck 3, (OL)& Truck 4, (ML) &Truck 5, (IL)**	0.000	0.000
	Truck 6, (O.L)& Truck 1, (M.L) &Truck 2, (I.L)	0.001	0.000
M_36	**Multiple presence**	0.001	-0.001

Table 5.54 – Summary of peak measured displacements (inches) in displacement sensor CH_19 installed on Span 36 to measure the displacement at new sub-floorbeam-to-stringer connection

Span 38, displacement at existing sub-floorbeam-to-stringer connection			
Test name	Truck in lane	CH_47, (inches)	
		δ_{max}	δ_{min}
CRL1_36	Truck 1, (O.L)	0.000	-0.001
	Truck 2, (O.L)	0.000	-0.001
	Truck 3, (M.L)	0.000	-0.001
	Truck 4, (M.L)	0.000	-0.001
	Truck 5, (I.L)	0.000	0.000
	Truck 6, (I.L)	0.000	0.000
CRL2_36	Truck 1, (O.L)& Truck 2, (M.L)	0.000	-0.002
	Truck 3, (OL)& Truck 4, (ML)	0.000	-0.002
CRL3_36	Truck 5, (M.L)& Truck 6, (I.L)	0.000	-0.001
	Truck 1, (ML)& Truck 2, (IL)	0.000	-0.001
CRL4_36	Truck 3, (OL)& Truck 4, (ML) &Truck 5, (IL)	0.000	-0.002
	Truck 6, (O.L)& Truck 1, (M.L) &Truck 2, (I.L)	0.000	-0.002
M_36 (raw)	Multiple presence	0.0011	-0.0007
M_36 (modified)	Multiple presence	0.0001	-0.0017

Table 5.55 – Summary of peak measured displacements (inches) in displacement sensor CH_47 installed on Span 38 to measure the displacement at existing sub-floorbeam-to-stringer connection

Span 45, displacement at new sub-floorbeam-to-stringer connection			
Test name	**Truck in lane**	**CH_18, (inches)**	
		δ_{max}	δ_{min}
CRL1_45	**Truck 1, (O.L)**	0.001	0.000
	Truck 2, (O.L)	0.001	0.000
	Truck 3, (M.L)	0.001	0.000
	Truck 4, (M.L)	0.000	0.000
	Truck 5, (I.L)	0.000	0.000
	Truck 6, (I.L)	0.000	0.000
CRL2_45	**Truck 1, (O.L)& Truck 2, (M.L)**	0.001	0.000
	Truck 3, (OL)& Truck 4, (ML)	0.001	0.000
CRL3_45	**Truck 5, (M.L)& Truck 6, (I.L)**	0.000	0.000
	Truck 1, (ML)& Truck 2, (IL)	0.000	0.000
[1]CRL4_45	**Truck 3, (OL)& Truck 4, (ML) &Truck 5, (IL)**	NA	NA
	Truck 6, (O.L)& Truck 1, (M.L) &Truck 2, (I.L)	NA	NA
M_45	**Multiple presence**	0.000	0.000

Note:
1. Data for this test were not retrieved

Table 5.56 – Summary of peak measured displacements (inches) in displacement sensor CH_18 installed on Span 45 to measure the displacement at new sub-floorbeam-to-stringer connection

5.3.15 Displacement between Bottom Flange of Rib Plate and New and Existing Sub-floorbeam

Span 34, displacement between the bottom flange of the rib plate and existing sub-floorbeam					
Test name	Truck in lane	CH_7, (inches)		CH_8, (inches)	
		δ_{max}	δ_{min}	δ_{max}	δ_{min}
CRL1_34	Truck 1, (O.L)	--	--	0.002	-0.004
	Truck 2, (O.L)	--	--	0.002	-0.004
	Truck 3, (M.L)	--	--	0.003	-0.006
	Truck 4, (M.L)	--	--	0.000	-0.008
	Truck 5, (I.L)	--	--	0.003	-0.002
	Truck 6, (I.L)	--	--	0.003	-0.002
CRL2_34	Truck 1, (O.L)& Truck 2, (M.L)	0.008	-0.003	0.000	-0.011
	Truck 3, (OL)& Truck 4, (ML)	0.002	-0.066	0.001	-0.010
CRL3_34	Truck 5, (M.L)& Truck 6, (I.L)	--	--	0.001	-0.007
	Truck 1, (ML)& Truck 2, (IL)	--	--	0.002	-0.008
CRL4_34	Truck 3, (OL)& Truck 4, (ML) &Truck 5, (IL)	--	--	0.003	-0.008
	Truck 6, (O.L)& Truck 1, (M.L) &Truck 2, (I.L)	--	--	0.004	-0.010
M_34	Multiple presence	0.010	-0.006	0.004	-0.010

Note:
"--" indicates significant noise in the data.

Table 5.57 – Summary of peak measured displacements (inches) in displacement sensors CH_7 and CH_8 installed on Span 34 to measure the displacement between the bottom flange of rib plate and existing sub-floorbeam

Span 34, displacement between the bottom flange of the rib plate and existing sub-floorbeam					
Test name	Truck in lane	CH_9, (inches)		CH_10, (inches)	
		δ_{max}	δ_{min}	δ_{max}	δ_{min}
CRL1_34	Truck 1, (O.L)	0.002	-0.460	0.002	-0.007
	Truck 2, (O.L)	0.000	-0.407	0.002	-0.007
	Truck 3, (M.L)	0.007	-0.403	0.003	-0.016
	Truck 4, (M.L)	0.005	-0.508	0.003	-0.016
	Truck 5, (I.L)	0.001	-0.083	0.001	-0.006
	Truck 6, (I.L)	0.005	-0.123	0.002	-0.006
CRL2_34	Truck 1, (O.L)& Truck 2, (M.L)	0.000	-0.492	0.004	-0.018
	Truck 3, (OL)& Truck 4, (ML)	0.000	-0.451	0.004	-0.017
CRL3_34	Truck 5, (M.L)& Truck 6, (I.L)	0.002	-0.523	0.004	-0.018
	Truck 1, (ML)& Truck 2, (IL)	0.005	-0.505	0.004	-0.017
CRL4_34	Truck 3, (OL)& Truck 4, (ML) &Truck 5, (IL)	0.005	-0.525	0.005	-0.017
	Truck 6, (O.L)& Truck 1, (M.L) &Truck 2, (I.L)	0.036	-0.470	0.004	-0.020
M_34	Multiple presence	0.002	-0.483	0.007	-0.018

Table 5.58 – Summary of peak measured displacements (inches) in displacement sensors CH_9 and CH_10 installed on Span 34 to measure the displacement between the bottom flange of rib plate and existing sub-floorbeam

Span 34, displacement between the bottom flange of the rib plate and existing sub-floorbeam					
Test name	Truck in lane	CH_19, (inches)		CH_20, (inches)	
		δ_{max}	δ_{min}	δ_{max}	δ_{min}
CRL1_34	Truck 1, (O.L)	0.001	-0.003	0.002	0.000
	Truck 2, (O.L)	0.001	-0.003	0.003	0.000
	Truck 3, (M.L)	0.002	-0.003	0.003	0.000
	Truck 4, (M.L)	0.001	-0.002	0.002	0.000
	Truck 5, (I.L)	0.001	-0.001	0.000	-0.001
	Truck 6, (I.L)	0.001	-0.001	0.001	0.000
CRL2_34	Truck 1, (O.L)& Truck 2, (M.L)	0.002	-0.005	0.004	-0.001
	Truck 3, (OL)& Truck 4, (ML)	0.002	-0.004	0.003	-0.001
CRL3_34	Truck 5, (M.L)& Truck 6, (I.L)	0.002	-0.002	0.002	-0.001
	Truck 1, (ML)& Truck 2, (IL)	0.002	-0.004	0.002	-0.003
CRL4_34	Truck 3, (OL)& Truck 4, (ML) &Truck 5, (IL)	0.004	-0.003	0.004	0.000
	Truck 6, (O.L)& Truck 1, (M.L) &Truck 2, (I.L)	0.003	-0.005	0.004	-0.001
M_34	Multiple presence	0.003	-0.006	0.003	-0.003

Table 5.59 – Summary of peak measured displacements (inches) in displacement sensors CH_19 and CH_20 installed on Span 34 to measure the displacement between the bottom flange of rib plate and existing sub-floorbeam

Span 34, displacement between the bottom flange of the rib plate and existing sub-floorbeam					
Test name	Truck in lane	CH_21, (inches)		CH_22, (inches)	
		δ_{max}	δ_{min}	δ_{max}	δ_{min}
CRL1_34	Truck 1, (O.L)	0.004	0.001	0.005	-0.002
	Truck 2, (O.L)	0.011	0.008	0.016	0.011
	Truck 3, (M.L)	0.012	0.007	0.015	0.010
	Truck 4, (M.L)	0.012	0.004	0.017	-0.260
	Truck 5, (I.L)	0.008	0.001	-0.003	-0.104
	Truck 6, (I.L)	0.009	-0.009	-0.013	-0.216
CRL2_34	Truck 1, (O.L)& Truck 2, (M.L)	0.001	-0.004	0.000	-0.002
	Truck 3, (OL)& Truck 4, (ML)	0.001	-0.005	0.000	-0.002
CRL3_34	Truck 5, (M.L)& Truck 6, (I.L)	0.001	-0.004	0.003	-0.001
	Truck 1, (ML)& Truck 2, (IL)	0.001	-0.003	0.003	-0.001
CRL4_34	Truck 3, (OL)& Truck 4, (ML) &Truck 5, (IL)	0.003	-0.002	0.003	0.002
	Truck 6, (O.L)& Truck 1, (M.L) &Truck 2, (I.L)	0.001	-0.004	0.000	0.000
M_34	Multiple presence	--	--	--	--

Note:
"--" indicates significant noise in the data.

Table 5.60 – Summary of peak measured displacements (inches) measured in displacement sensors CH_21 and CH_22 installed on Span 34 to measure the displacement between the bottom flange of rib plate and existing sub-floorbeam

Span 35, displacement between the bottom flange of the rib plate and existing sub-floorbeam					
Test name	Truck in lane	CH_48, (inches)		CH_49, (inches)	
		δ_{max}	δ_{min}	δ_{max}	δ_{min}
CRL1_34	Truck 1, (O.L)	0.000	-0.001	0.002	-0.001
	Truck 2, (O.L)	0.001	-0.002	0.002	-0.001
	Truck 3, (M.L)	0.001	-0.001	0.002	-0.002
	Truck 4, (M.L)	0.000	-0.001	0.000	-0.003
	Truck 5, (I.L)	0.000	-0.002	-0.001	-0.004
	Truck 6, (I.L)	0.000	-0.002	-0.002	-0.004
CRL2_34	Truck 1, (O.L)& Truck 2, (M.L)	0.000	-0.003	0.004	0.000
	Truck 3, (OL)& Truck 4, (ML)	0.000	-0.003	0.004	-0.001
CRL3_34	Truck 5, (M.L)& Truck 6, (I.L)	0.000	-0.002	0.003	-0.003
	Truck 1, (ML)& Truck 2, (IL)	0.000	-0.003	0.002	-0.003
CRL4_34	Truck 3, (OL)& Truck 4, (ML) &Truck 5, (IL)	-0.007	-0.011	-0.033	-0.040
	Truck 6, (O.L)& Truck 1, (M.L) &Truck 2, (I.L)	0.000	-0.004	0.004	-0.003
M_34	Multiple presence	0.000	-0.005	0.005	0.000

Table 5.61 – Summary of peak measured displacements (inches) measured in displacement sensors CH_48 and CH_49 installed on Span 35 to measure the displacement between the bottom flange of rib plate and existing sub-floorbeam

Span 36, displacement between the bottom flange of the rib plate and the new sub-floorbeam					
Test name	Truck in lane	CH_32, (inches)		CH_27, (inches)	
		δ_{max}	δ_{min}	δ_{max}	δ_{min}
CRL1_36	Truck 1, (O.L)	0.002	0.000	0.001	0.000
	Truck 2, (O.L)	0.002	0.000	0.002	0.000
	Truck 3, (M.L)	0.003	0.000	0.004	-0.002
	Truck 4, (M.L)	0.003	0.000	0.005	-0.002
	Truck 5, (I.L)	0.001	0.000	0.001	0.000
	Truck 6, (I.L)	0.000	-0.001	0.001	0.000
CRL2_36	Truck 1, (O.L)& Truck 2, (M.L)	0.004	-0.002	0.006	-0.002
	Truck 3, (OL)& Truck 4, (ML)	0.004	-0.002	0.006	-0.002
CRL3_36	Truck 5, (M.L)& Truck 6, (I.L)	0.003	0.000	0.005	-0.001
	Truck 1, (ML)& Truck 2, (IL)	0.003	-0.001	0.005	0.000
CRL4_36	Truck 3, (OL)& Truck 4, (ML) &Truck 5, (IL)	0.003	0.000	0.006	-0.001
	Truck 6, (O.L)& Truck 1, (M.L) &Truck 2, (I.L)	0.005	0.000	0.007	0.000
M_36	Multiple presence	0.005	-0.001	0.005	-0.001

Table 5.62 – Summary of peak measured displacements (inches) in displacement sensors CH_32 and CH_27 installed on Span 36 to measure the displacement between the bottom flange of rib plate and new sub-floorbeam

Span 38, displacement between the bottom flange of the rib plate and existing sub-floorbeam					
Test name	Truck in lane	CH_53, (inches)		CH_54, (inches)	
		δ_{max}	δ_{min}	δ_{max}	δ_{min}
CRL1_36	Truck 1, (O.L)	0.008	-0.001	0.010	-0.001
	Truck 2, (O.L)	0.008	-0.001	0.010	-0.001
	Truck 3, (M.L)	0.007	-0.002	0.013	-0.003
	Truck 4, (M.L)	0.007	-0.002	0.013	-0.003
	Truck 5, (I.L)	0.003	-0.001	0.006	-0.001
	Truck 6, (I.L)	0.003	-0.001	0.006	-0.001
CRL2_36	Truck 1, (O.L)& Truck 2, (M.L)	0.017	-0.006	0.023	-0.005
	Truck 3, (OL)& Truck 4, (ML)	0.016	-0.002	0.023	-0.002
CRL3_36	Truck 5, (M.L)& Truck 6, (I.L)	0.010	-0.001	0.018	-0.002
	Truck 1, (ML)& Truck 2, (IL)	0.006	-0.001	0.010	-0.001
CRL4_36	Truck 3, (OL)& Truck 4, (ML) &Truck 5, (IL)	0.017	-0.001	0.025	-0.002
	Truck 6, (O.L)& Truck 1, (M.L) &Truck 2, (I.L)	0.019	-0.001	0.028	-0.001
M_36 (raw)	Multiple presence	0.007	-0.014	0.011	-0.018
M_36 (modified)	Multiple presence	0.019	-0.002	0.028	-0.001

Table 5.63 – Summary of peak measured displacements (inches) in displacement sensors CH_53 and CH_54 installed on Span 38 to measure the displacement between the bottom flange of rib plate and existing sub-floorbeam

Span 45, displacement between the bottom flange of the rib plate and the new sub-floorbeam					
Test name	Truck in lane	CH_23, (inches)		CH_24, (inches)	
		δ_{max}	δ_{min}	δ_{max}	δ_{min}
CRL1_45	Truck 1, (O.L)	0.002	0.000	0.004	0.000
	Truck 2, (O.L)	0.002	0.000	0.004	0.000
	Truck 3, (M.L)	0.005	-0.001	0.005	-0.002
	Truck 4, (M.L)	0.005	-0.001	0.004	-0.001
	Truck 5, (I.L)	0.001	0.000	0.001	0.000
	Truck 6, (I.L)	0.001	0.000	0.001	0.000
CRL2_45	Truck 1, (O.L)& Truck 2, (M.L)	0.006	-0.001	0.007	-0.001
	Truck 3, (OL)& Truck 4, (ML)	0.006	0.000	0.006	-0.001
CRL3_45	Truck 5, (M.L)& Truck 6, (I.L)	0.006	0.000	0.004	-0.001
	Truck 1, (ML)& Truck 2, (IL)	0.006	-0.001	0.005	-0.003
[1]CRL4_45	Truck 3, (OL)& Truck 4, (ML) &Truck 5, (IL)	NA	NA	NA	NA
	Truck 6, (O.L)& Truck 1, (M.L) &Truck 2, (I.L)	NA	NA	NA	NA
M_45	Multiple presence	0.006	0.000	0.006	0.000

Note:
1. Data for this test were not retrieved

Table 5.64 – Summary of peak measured displacements (inches) in displacement sensors CH_23 and CH_24 installed on Span 45 to measure the displacement between the bottom flange of rib plate and new sub-floorbeam

5.3.16 Displacement between Bottom Flange of the Stringer and the Top Flange of the Transverse Stiffener of the Floorbeam

Span 35, displacement between the bottom flange of the stringer and the top flange of the transverse stiffener of the floorbeam			
Test name	Truck in lane	CH_38, (inches)	
		δ_{max}	δ_{min}
CRL1_34	Truck 1, (O.L)	--	--
	Truck 2, (O.L)	--	--
	Truck 3, (M.L)	--	--
	Truck 4, (M.L)	--	--
	Truck 5, (I.L)	--	--
	Truck 6, (I.L)	--	--
CRL2_34	Truck 1, (O.L)& Truck 2, (M.L)	--	--
	Truck 3, (OL)& Truck 4, (ML)	--	--
CRL3_34	Truck 5, (M.L)& Truck 6, (I.L)	--	--
	Truck 1, (ML)& Truck 2, (IL)	--	--
CRL4_34	Truck 3, (OL)& Truck 4, (ML) &Truck 5, (IL)	0.003	0.000
	Truck 6, (O.L)& Truck 1, (M.L) &Truck 2, (I.L)	0.003	0.000
M_34	Multiple presence	--	--

Note:
"--" indicates significant noise in the data.

Table 5.64 - Summary of peak measured displacements (inches) in displacement sensor CH_38 installed on Span 35 to measure the displacement between the bottom flange of the stringer and the top flange of the transverse stiffener of the floorbeam

Span 36, displacement between the bottom flange of the stringer and the top flange of the transverse stiffener of the floorbeam			
Test name	Truck in lane	CH_15, (inches)	
		δ_{max}	δ_{min}
CRL1_36	Truck 1, (O.L)	0.002	0.000
	Truck 2, (O.L)	0.002	0.000
	Truck 3, (M.L)	0.001	-0.002
	Truck 4, (M.L)	0.001	-0.002
	Truck 5, (I.L)	0.001	0.000
	Truck 6, (I.L)	0.001	0.000
CRL2_36	Truck 1, (O.L)& Truck 2, (M.L)	0.003	-0.003
	Truck 3, (OL)& Truck 4, (ML)	0.004	-0.002
CRL3_36	Truck 5, (M.L)& Truck 6, (I.L)	0.002	-0.002
	Truck 1, (ML)& Truck 2, (IL)	0.002	-0.002
CRL4_36	Truck 3, (OL)& Truck 4, (ML) &Truck 5, (IL)	0.004	-0.002
	Truck 6, (O.L)& Truck 1, (M.L) &Truck 2, (I.L)	0.005	-0.001
M_36	Multiple presence	0.006	-0.003

Table 5.66 – Summary of peak measured displacements (inches) in displacement sensor CH_15 installed on Span 36 to measure the displacement between the bottom flange of the stringer and the top flange of the transverse stiffener of the floorbeam

Span 38, displacement between the bottom flange of the stringer and the top flange of the transverse stiffener of the floorbeam			
Test name	Truck in lane	CH_43, (inches)	
		δ_{max}	δ_{min}
CRL1_36	Truck 1, (O.L)	0.000	-0.001
	Truck 2, (O.L)	0.000	-0.001
	Truck 3, (M.L)	0.000	-0.001
	Truck 4, (M.L)	0.000	-0.001
	Truck 5, (I.L)	0.000	0.000
	Truck 6, (I.L)	0.000	0.000
CRL2_36	Truck 1, (O.L)& Truck 2, (M.L)	0.000	-0.002
	Truck 3, (OL)& Truck 4, (ML)	0.000	-0.002
CRL3_36	Truck 5, (M.L)& Truck 6, (I.L)	0.000	-0.002
	Truck 1, (ML)& Truck 2, (IL)	0.000	-0.001
CRL4_36	Truck 3, (OL)& Truck 4, (ML) &Truck 5, (IL)	0.000	-0.002
	Truck 6, (O.L)& Truck 1, (M.L) &Truck 2, (I.L)	0.000	-0.002
M_36 (raw)	Multiple presence	0.000	-0.00207
M_36 (modified)	Multiple presence	0.00157	-0.0005

Table 5.67 – Summary of peak measured displacements (inches) in displacement sensor CH_43 installed on Span 38 to measure the displacement between the bottom flange of the stringer and the top flange of the transverse stiffener of the floorbeam

Span 45, displacement between the bottom flange of the stringer and the top flange of the transverse stiffener of the floorbeam			
Test name	Truck in lane	CH_16, (inches)	
		δ_{max}	δ_{min}
CRL1_45	Truck 1, (O.L)	0.000	-0.001
	Truck 2, (O.L)	0.000	-0.001
	Truck 3, (M.L)	0.001	-0.001
	Truck 4, (M.L)	0.001	-0.001
	Truck 5, (I.L)	0.000	0.000
	Truck 6, (I.L)	0.000	0.000
CRL2_45	Truck 1, (O.L)& Truck 2, (M.L)	0.001	-0.002
	Truck 3, (OL)& Truck 4, (ML)	0.001	-0.002
CRL3_45	Truck 5, (M.L)& Truck 6, (I.L)	0.001	-0.002
	Truck 1, (ML)& Truck 2, (IL)	0.001	-0.002
[1]CRL4_45	Truck 3, (OL)& Truck 4, (ML) &Truck 5, (IL)	NA	NA
	Truck 6, (O.L)& Truck 1, (M.L) &Truck 2, (I.L)	NA	NA
M_45	Multiple presence	0.000	-0.005

Note:
1. Data for this test were not retrieved

Table 5.68 – Summary of peak measured displacements (inches) in displacement sensor CH_16 installed on Span 45 to measure the displacement between the bottom flange of the stringer and the top flange of the transverse stiffener of the floorbeam

5.3.17 Displacement between the Web and the Flange of the Floorbeam

Span 34, displacement between the floorbeam web and the floorbeam flange			
Test name	Truck in lane	CH_11, (inches)	
		δ_{max}	δ_{min}
CRL1_34	Truck 1, (O.L)	--	--
	Truck 2, (O.L)	--	--
	Truck 3, (M.L)	--	--
	Truck 4, (M.L)	--	--
	Truck 5, (I.L)	--	--
	Truck 6, (I.L)	--	--
CRL2_34	Truck 1, (O.L)& Truck 2, (M.L)	0.001	-0.002
	Truck 3, (OL)& Truck 4, (ML)	0.001	-0.002
CRL3_34	Truck 5, (M.L)& Truck 6, (I.L)	0.003	-0.002
	Truck 1, (ML)& Truck 2, (IL)	0.002	-0.003
CRL4_34	Truck 3, (OL)& Truck 4, (ML) &Truck 5, (IL)	0.004	-0.002
	Truck 6, (O.L)& Truck 1, (M.L) &Truck 2, (I.L)	0.004	-0.002
M_34	Multiple presence	0.004	-0.001

Table 5.69 – Summary of peak measured displacements (inches) in displacement sensor CH_11 installed on Span 34 to measure the displacement between the floorbeam web and the floorbeam flange

Span 35, displacement between the floorbeam web and the floorbeam flange			
Test name	Truck in lane	CH_37, (inches)	
		δ_{max}	δ_{min}
CRL1_34	Truck 1, (O.L)	0.004	-0.005
	Truck 2, (O.L)	0.004	-0.008
	Truck 3, (M.L)	0.005	-0.009
	Truck 4, (M.L)	0.005	-0.001
	Truck 5, (I.L)	0.001	-0.004
	Truck 6, (I.L)	0.002	-0.001
CRL2_34	Truck 1, (O.L)& Truck 2, (M.L)	0.002	-0.004
	Truck 3, (OL)& Truck 4, (ML)	0.003	-0.006
CRL3_34	Truck 5, (M.L)& Truck 6, (I.L)	0.005	0.000
	Truck 1, (ML)& Truck 2, (IL)	0.004	-0.001
CRL4_34	Truck 3, (OL)& Truck 4, (ML) &Truck 5, (IL)	0.007	0.000
	Truck 6, (O.L)& Truck 1, (M.L) &Truck 2, (I.L)	0.007	0.000
M_34	Multiple presence	0.007	0.000

Table 5.70 – Summary of peak measured displacements (inches) in displacement sensor CH_37 installed on Span 35 to measure the displacement between the floorbeam web and the floorbeam flange

Span 36, displacement between the floorbeam web and the floorbeam flange			
Test name	Truck in lane	CH_14, (inches)	
		δ_{max}	δ_{min}
CRL1_36	Truck 1, (O.L)	0.000	0.000
	Truck 2, (O.L)	0.000	0.000
	Truck 3, (M.L)	0.000	0.000
	Truck 4, (M.L)	0.000	0.000
	Truck 5, (I.L)	0.000	0.000
	Truck 6, (I.L)	0.000	0.000
CRL2_36	Truck 1, (O.L)& Truck 2, (M.L)	0.000	-0.003
	Truck 3, (OL)& Truck 4, (ML)	0.001	-0.002
CRL3_36	Truck 5, (M.L)& Truck 6, (I.L)	0.001	0.000
	Truck 1, (ML)& Truck 2, (IL)	0.001	0.000
CRL4_36	Truck 3, (OL)& Truck 4, (ML) &Truck 5, (IL)	0.002	0.000
	Truck 6, (O.L)& Truck 1, (M.L) &Truck 2, (I.L)	0.003	0.001
M_36	Multiple presence	0.002	-0.001

Table 5.71 – Summary of peak measured displacements (inches) in displacement sensor CH_14 installed on Span 36 to measure the displacement between the floorbeam web and the floorbeam flange

Span 38, displacement between the floorbeam web and the floorbeam flange			
Test name	Truck in lane	CH_42, (inches)	
		δ_{max}	δ_{min}
CRL1_36	Truck 1, (O.L)	0.000	-0.013
	Truck 2, (O.L)	0.001	-0.012
	Truck 3, (M.L)	0.001	-0.010
	Truck 4, (M.L)	0.001	-0.010
	Truck 5, (I.L)	0.000	-0.007
	Truck 6, (I.L)	0.001	-0.008
CRL2_36	Truck 1, (O.L)& Truck 2, (M.L)	0.001	-0.022
	Truck 3, (OL)& Truck 4, (ML)	0.001	-0.021
CRL3_36	Truck 5, (M.L)& Truck 6, (I.L)	0.001	-0.019
	Truck 1, (ML)& Truck 2, (IL)	0.000	-0.015
CRL4_36	Truck 3, (OL)& Truck 4, (ML) &Truck 5, (IL)	0.002	-0.028
	Truck 6, (O.L)& Truck 1, (M.L) &Truck 2, (I.L)	0.002	-0.030
M_36 (raw)	Multiple presence	0.026	-0.007
M_36 (modified)	Multiple presence	0.003	-0.030

Table 5.72 – Summary of peak measured displacements (inches) in displacement sensor CH_42 installed on Span 38 to measure the displacement between the floorbeam web and the floorbeam flange

Span 45, displacement between the floorbeam web and the floorbeam flange			
Test name	Truck in lane	CH_14, (inches)	
		δ_{max}	δ_{min}
CRL1_45	Truck 1, (O.L)	0.001	0.000
	Truck 2, (O.L)	0.001	0.000
	Truck 3, (M.L)	0.001	-0.001
	Truck 4, (M.L)	0.001	-0.001
	Truck 5, (I.L)	0.001	0.000
	Truck 6, (I.L)	0.001	0.000
CRL2_45	Truck 1, (O.L)& Truck 2, (M.L)	0.001	-0.002
	Truck 3, (OL)& Truck 4, (ML)	0.001	-0.002
CRL3_45	Truck 5, (M.L)& Truck 6, (I.L)	0.001	-0.002
	Truck 1, (ML)& Truck 2, (IL)	0.001	-0.002
[1]CRL4_45	Truck 3, (OL)& Truck 4, (ML) &Truck 5, (IL)	NA	NA
	Truck 6, (O.L)& Truck 1, (M.L) &Truck 2, (I.L)	NA	NA
M_45	Multiple presence	0.002	-0.001

Note:
1. Data for this test were not retrieved

Table 5.73 – Summary of peak measured displacements (inches) in displacement sensor CH_14 installed on Span 45 to measure the displacement between the floorbeam web and the floorbeam flange

5.3.18 Displacement between the Top Flange of the Girder and the Bottom Flange of the Existing and New Sub-floorbeam

Span 35, displacement between the top flange of the main girder and the bottom flange of the existing sub-floorbeam			
Test name	Truck in lane	CH_42, (inches)	
		δ_{max}	δ_{min}
CRL1_34	Truck 1, (O.L)	0.033	-0.005
	Truck 2, (O.L)	0.032	-0.003
	Truck 3, (M.L)	0.028	-0.003
	Truck 4, (M.L)	0.025	-0.002
	Truck 5, (I.L)	0.020	-0.003
	Truck 6, (I.L)	0.020	-0.004
CRL2_34	Truck 1, (O.L)& Truck 2, (M.L)	0.046	-0.003
	Truck 3, (OL)& Truck 4, (ML)	0.044	-0.003
CRL3_34	Truck 5, (M.L)& Truck 6, (I.L)	0.040	-0.005
	Truck 1, (ML)& Truck 2, (IL)	0.039	-0.006
CRL4_34	Truck 3, (OL)& Truck 4, (ML) &Truck 5, (IL)	0.019	-0.030
	Truck 6, (O.L)& Truck 1, (M.L) &Truck 2, (I.L)	0.048	-0.005
M_34	Multiple presence	0.058	0.000

Table 5.74 – Summary of peak measured displacements (inches) in displacement sensor CH_42 installed on Span 35 to measure the displacement between the top flange of the main girder and the bottom flange of the existing sub-floorbeam

Span 36, displacement between the top flange of the main girder and the bottom flange of the new sub-floorbeam			
Test name	**Truck in lane**	**CH_26, (inches)**	
		δ_{max}	δ_{min}
CRL1_36	**Truck 1, (O.L)**	0.000	-0.013
	Truck 2, (O.L)	0.000	-0.013
	Truck 3, (M.L)	0.000	-0.010
	Truck 4, (M.L)	0.000	-0.010
	Truck 5, (I.L)	0.000	-0.009
	Truck 6, (I.L)	0.001	-0.009
CRL2_36	**Truck 1, (O.L)& Truck 2, (M.L)**	-0.002	-0.022
	Truck 3, (OL)& Truck 4, (ML)	0.002	-0.019
CRL3_36	**Truck 5, (M.L)& Truck 6, (I.L)**	0.002	-0.015
	Truck 1, (ML)& Truck 2, (IL)	0.002	-0.015
CRL4_36	**Truck 3, (OL)& Truck 4, (ML) &Truck 5, (IL)**	0.001	-0.021
	Truck 6, (O.L)& Truck 1, (M.L) &Truck 2, (I.L)	0.003	-0.024
M_36	**Multiple presence**	0.005	-0.023

Table 5.75 – Summary of peak measured displacements (inches) in displacement sensor CH_26 installed on Span 36 to measure the displacement between the top flange of the main girder and the bottom flange of the new sub-floorbeam

Span 38, displacement between the top flange of the main girder and the bottom flange of the existing sub-floorbeam			
Test name	Truck in lane	CH_52, (inches)	
		δ_{max}	δ_{min}
CRL1_36	Truck 1, (O.L)	0.003	-0.045
	Truck 2, (O.L)	0.005	-0.044
	Truck 3, (M.L)	0.003	-0.035
	Truck 4, (M.L)	0.003	-0.034
	Truck 5, (I.L)	0.003	-0.026
	Truck 6, (I.L)	0.005	-0.028
CRL2_36	Truck 1, (O.L)& Truck 2, (M.L)	0.006	-0.078
	Truck 3, (OL)& Truck 4, (ML)	0.007	-0.072
CRL3_36	Truck 5, (M.L)& Truck 6, (I.L)	0.006	-0.065
	Truck 1, (ML)& Truck 2, (IL)	0.003	-0.052
CRL4_36	Truck 3, (OL)& Truck 4, (ML) &Truck 5, (IL)	0.011	-0.099
	Truck 6, (O.L)& Truck 1, (M.L) &Truck 2, (I.L)	0.008	-0.105
M_36 (raw)	Multiple presence	0.090	-0.023
M_36 (modified)	Multiple presence	0.000	-0.113

Table 5.76 – Summary of peak measured displacements (inches) in displacement sensor CH_52 installed on Span 38 to measure the displacement between the top flange of the main girder and the bottom flange of the existing sub-floorbeam

Span 45, displacement between the top flange of the main girder and the bottom flange of the new sub-floorbeam			
Test name	**Truck in lane**	**CH_17, (inches)**	
		δ_{max}	δ_{min}
CRL1_45	**Truck 1, (O.L)**	0.000	-0.011
	Truck 2, (O.L)	0.001	-0.011
	Truck 3, (M.L)	0.001	-0.009
	Truck 4, (M.L)	0.001	-0.009
	Truck 5, (I.L)	0.000	-0.006
	Truck 6, (I.L)	0.000	-0.007
CRL2_45	**Truck 1, (O.L)& Truck 2, (M.L)**	0.001	-0.018
	Truck 3, (OL)& Truck 4, (ML)	0.000	-0.017
CRL3_45	**Truck 5, (M.L)& Truck 6, (I.L)**	0.000	-0.015
	Truck 1, (ML)& Truck 2, (IL)	0.000	-0.015
[1]CRL4_45	**Truck 3, (OL)& Truck 4, (ML) &Truck 5, (IL)**	NA	NA
	Truck 6, (O.L)& Truck 1, (M.L) &Truck 2, (I.L)	NA	NA
M_45	**Multiple presence**	0.000	-0.023

Note:
1. Data for this test were not retrieved

Table 5.77 – Summary of peak measured displacements (inches) in displacement sensor CH_17 installed on Span 45 to measure the displacement between the top flange of the main girder and the bottom flange of the new sub-floorbeam

5.3.19 Longitudinal Displacement between the Pier and the End of the Girder

Span 35, longitudinal displacement between the pier and the end of the girder			
Test name	Truck in lane	CH_36, (inches)	
		δ_{max}	δ_{min}
CRL1_34	Truck 1, (O.L)	0.017	-0.005
	Truck 2, (O.L)	0.018	-0.013
	Truck 3, (M.L)	0.017	-0.012
	Truck 4, (M.L)	0.018	0.000
	Truck 5, (I.L)	0.011	-0.003
	Truck 6, (I.L)	0.012	-0.001
CRL2_34	Truck 1, (O.L)& Truck 2, (M.L)	0.023	-0.006
	Truck 3, (OL)& Truck 4, (ML)	0.019	-0.010
CRL3_34	Truck 5, (M.L)& Truck 6, (I.L)	0.024	-0.001
	Truck 1, (ML)& Truck 2, (IL)	0.021	0.001
CRL4_34	Truck 3, (OL)& Truck 4, (ML) &Truck 5, (IL)	0.040	0.002
	Truck 6, (O.L)& Truck 1, (M.L) &Truck 2, (I.L)	0.042	0.000
M_34	Multiple presence	0.040	-0.003

Table 5.78 – Summary of peak measured displacements (inches) in displacement sensor CH_36 installed on Span 35 to measure the longitudinal displacement between the pier and the end of the girder

Span 36, longitudinal displacement between the pier and the end of the girder			
Test name	**Truck in lane**	**CH_13, (inches)**	
		δ_{max}	δ_{min}
CRL1_36	**Truck 1, (O.L)**	0.002	-0.015
	Truck 2, (O.L)	0.000	-0.015
	Truck 3, (M.L)	0.002	-0.012
	Truck 4, (M.L)	0.001	-0.011
	Truck 5, (I.L)	0.001	-0.007
	Truck 6, (I.L)	0.001	-0.007
CRL2_36	**Truck 1, (O.L)& Truck 2, (M.L)**	0.004	-0.026
	Truck 3, (OL)& Truck 4, (ML)	0.008	-0.018
CRL3_36	**Truck 5, (M.L)& Truck 6, (I.L)**	0.004	-0.015
	Truck 1, (ML)& Truck 2, (IL)	0.003	-0.014
CRL4_36	**Truck 3, (OL)& Truck 4, (ML) &Truck 5, (IL)**	0.001	-0.028
	Truck 6, (O.L)& Truck 1, (M.L) &Truck 2, (I.L)	0.000	-0.031
M_36	**Multiple presence**	0.008	-0.016

Table 5.79 – Summary of peak measured displacements (inches) in displacement sensor CH_13 installed on Span 36 to measure the longitudinal displacement between the pier and the end of the girder

Span 45, longitudinal displacement between the pier and the end of the girder			
Test name	Truck in lane	CH_43, (inches)	
		δ_{max}	δ_{min}
CRL1_45	Truck 1, (O.L)	0.024	-0.001
	Truck 2, (O.L)	0.023	-0.001
	Truck 3, (M.L)	0.019	0.005
	Truck 4, (M.L)	0.010	-0.003
	Truck 5, (I.L)	0.008	-0.002
	Truck 6, (I.L)	0.004	-0.002
CRL2_45	Truck 1, (O.L)& Truck 2, (M.L)	0.004	-0.035
	Truck 3, (OL)& Truck 4, (ML)	0.013	-0.005
CRL3_45	Truck 5, (M.L)& Truck 6, (I.L)	0.015	-0.002
	Truck 1, (ML)& Truck 2, (IL)	0.012	-0.005
[1]CRL4_45	Truck 3, (OL)& Truck 4, (ML) &Truck 5, (IL)	NA	NA
	Truck 6, (O.L)& Truck 1, (M.L) &Truck 2, (I.L)	NA	NA
M_45	Multiple presence	0.020	-0.005

Note:
1. Data for this test were not retrieved

Table 5.80 – Summary of peak measured displacements (inches) in displacement sensor CH_43 installed on Span 45 to measure the longitudinal displacement between the pier and the end of the girder

5.3.20 Relative Longitudinal Displacement between the Ends of the Girders

Span 35, relative displacement between the ends of the girders					
Test name	Truck in lane	CH_34, (inches)		CH_35, (inches)	
		δ_{max}	δ_{min}	δ_{max}	δ_{min}
CRL1_34	Truck 1, (O.L)	0.002	-0.001	0.000	-0.013
	Truck 2, (O.L)	0.002	0.000	0.001	-0.013
	Truck 3, (M.L)	0.003	0.000	0.000	-0.010
	Truck 4, (M.L)	0.002	-0.002	0.000	-0.014
	Truck 5, (I.L)	-0.050	-0.061	-0.001	-0.009
	Truck 6, (I.L)	-0.007	-0.010	0.000	-0.010
CRL2_34	Truck 1, (O.L)& Truck 2, (M.L)	0.002	-0.001	0.000	-0.021
	Truck 3, (OL)& Truck 4, (ML)	0.002	-0.001	0.001	-0.021
CRL3_34	Truck 5, (M.L)& Truck 6, (I.L)	0.002	-0.001	0.000	-0.020
	Truck 1, (ML)& Truck 2, (IL)	0.002	-0.001	0.001	-0.018
CRL4_34	Truck 3, (OL)& Truck 4, (ML) &Truck 5, (IL)	0.004	0.002	-0.054	-0.075
	Truck 6, (O.L)& Truck 1, (M.L) &Truck 2, (I.L)	0.002	0.000	-0.003	-0.028
M_34	Multiple presence	0.006	-0.007	0.002	-0.014

Table 5.81 – Summary of peak measured displacements (inches) in displacement sensors CH_34 and CH_35 installed on Span 35 to measure the relative longitudinal displacement between the end of the girders

Span 36, relative displacement between the ends of the girders					
Test name	Truck in lane	CH_11, (inches)		CH_12, (inches)	
		δ_{max}	δ_{min}	δ_{max}	δ_{min}
CRL1_36	Truck 1, (O.L)	0.064	-0.009	0.012	-0.001
	Truck 2, (O.L)	0.078	-0.010	0.012	0.000
	Truck 3, (M.L)	0.045	-0.012	0.009	-0.002
	Truck 4, (M.L)	0.057	-0.009	0.009	-0.001
	Truck 5, (I.L)	0.043	-0.009	0.006	-0.004
	Truck 6, (I.L)	0.048	-0.009	0.006	-0.005
CRL2_36	Truck 1, (O.L)& Truck 2, (M.L)	--	--	0.016	-0.004
	Truck 3, (OL)& Truck 4, (ML)	--	--	0.013	-0.006
CRL3_36	Truck 5, (M.L)& Truck 6, (I.L)	--	--	0.012	-0.003
	Truck 1, (ML)& Truck 2, (IL)	--	--	0.011	-0.002
CRL4_36	Truck 3, (OL)& Truck 4, (ML) &Truck 5, (IL)	--	--	0.022	0.001
	Truck 6, (O.L)& Truck 1, (M.L) &Truck 2, (I.L)	--	--	0.026	0.003
M_36	Multiple presence	--	--	0.015	-0.003

Note:
"--" indicates significant noise in the data.

Table 5.82 – Summary of peak measured displacements (inches) in displacement sensors CH_11 and CH_12 installed on Span 36 to measure the relative longitudinal displacement between the end of the girders

Span 45, relative displacement between the ends of the girders					
Test name	Truck in lane	CH_41, (inches)		CH_42, (inches)	
		δ_{max}	δ_{min}	δ_{max}	δ_{min}
CRL1_45	Truck 1, (O.L)	0.059	-0.008	0.001	-0.025
	Truck 2, (O.L)	0.053	-0.005	0.001	-0.024
	Truck 3, (M.L)	0.038	0.002	-0.004	-0.022
	Truck 4, (M.L)	0.040	0.005	0.003	-0.012
	Truck 5, (I.L)	0.037	-0.006	0.002	-0.009
	Truck 6, (I.L)	0.042	0.000	0.002	-0.006
CRL2_45	Truck 1, (O.L)& Truck 2, (M.L)	--	--	0.040	-0.004
	Truck 3, (OL)& Truck 4, (ML)	--	--	0.004	-0.020
CRL3_45	Truck 5, (M.L)& Truck 6, (I.L)	--	--	0.003	-0.033
	Truck 1, (ML)& Truck 2, (IL)	--	--	0.005	-0.016
[1]CRL4_45	Truck 3, (OL)& Truck 4, (ML) &Truck 5, (IL)	NA	NA	NA	NA
	Truck 6, (O.L)& Truck 1, (M.L) &Truck 2, (I.L)	NA	NA	NA	NA
M_45	Multiple presence	--	--	0.009	-0.045

Note:
"--" indicates significant noise in the data
1. Data for this test were not retrieved

Table 5.83 – Summary of peak measured displacements (inches) in displacement sensors CH_41 and CH_42 installed on Span 45 to measure the relative longitudinal displacement between the end of the girders

5.4 Results of Dynamic Tests

As previously discussed, two dynamic tests were conducted with test trucks traveling in the same lanes in each test. The difference between both tests is that the test trucks were traveling with speed of approximately 25 mph in the first test and approximately 50 mph in the second test. In both tests, dynamic vibration induced by the trucks is evident in the response. Figure 5.21 shows the response of strain gages CH_4 and CH_5 installed on the top and bottom flange, respectively, of the east girder in Span 34, as Truck 2 crossed in the northbound direction in the outside lane during test DYN1_34. The figure shows the dynamic vibration of the girder resulting from the truck crossing. It is difficult to determine the dynamic amplification factor when comparing the data of the dynamic tests to that of the crawl tests CRL1. The data show that in some cases the response in the crawl tests was higher than the dynamic tests and vise versa. This could be due to the fact that the southbound lanes were open to traffic while the tests were being conducted. Another possibility is, as previously noted, the response of some of the details is very sensitive to the transverse position of the test trucks, which could have been different in the dynamic tests compared to the crawl tests for a given lane. A maximum dynamic amplification factor of 2 was observed for the main girder response. A summary of the dynamic response of the instrumented locations to the crossing of the test trucks in both dynamic tests is listed below.

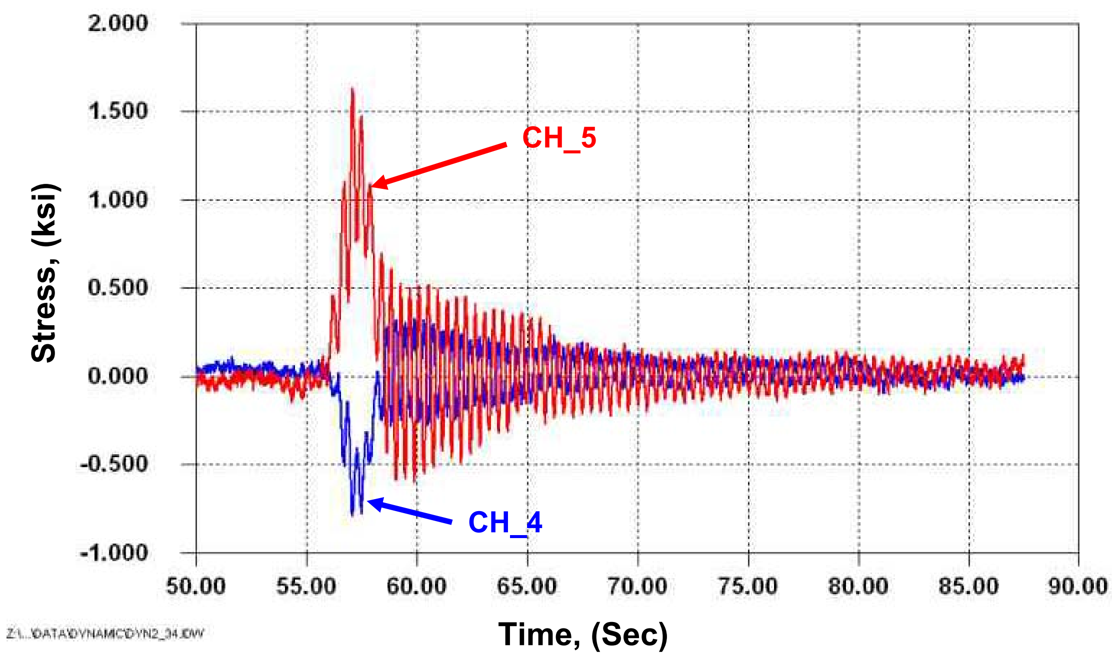


Figure 5.21 – Response of strain gage CH_4 & CH_5 installed on the top and bottom flange, respectively, of the east girder in Span 34, approximately 4 in north of midspan as Truck 2 crossed in the northbound direction in the outside lane during test DYN1_34

5.4.1 Stresses in the East Main Girder Flange

Span 34, top and bottom flange of east girder, 4ft north of midspan							
Test name	Truck in lane	CH_5, (ksi)			CH_4, (ksi)		
		σ_{max}	σ_{min}	$\Delta\sigma$	σ_{max}	σ_{min}	$\Delta\sigma$
DYN1_34	Truck 1, (O.L)	1.3	-0.2	1.5	0.0	-0.8	0.8
	Truck 2, (O.L)	1.2	-0.2	1.4	0.0	-0.7	0.7
	Truck 3, (M.L)	1.2	-0.1	1.3	0.5	-0.4	0.9
	Truck 4, (M.L)	1.0	-0.2	1.2	0.6	-0.1	0.7
	Truck 5, (I.L)	0.9	-0.2	1.1	0.1	-0.5	0.6
	Truck 6, (I.L)	0.9	-0.1	1.0	0.1	-0.5	0.6
DYN2_34	Truck 1, (O.L)	1.5	-0.3	1.8	0.2	-0.2	0.4
	Truck 2, (O.L)	1.6	-0.6	2.2	0.2	-0.3	0.5
	Truck 3, (M.L)	1.0	-0.1	1.1	0.1	-0.6	0.7
	Truck 4, (M.L)	1.0	-0.1	1.1	0.2	-0.5	0.7
	Truck 5, (I.L)	0.8	-0.2	1.0	0.2	-0.4	0.6
	Truck 6, (I.L)	1.1	-0.3	1.4	0.2	-0.5	0.7

Table 5.84 – Summary of peak stresses (ksi) measured in strain gages CH_4 and CH_5 installed on the top and bottom flange, respectively, of the east girder in Span 34, approximately 4 in north of midspan as the test trucks crossed over the span in the northbound direction in the dynamic tests

Span 35, top and bottom flange of east girder, 4ft north of midspan							
Test name	Truck in lane	CH_55, (ksi)			CH_54, (ksi)		
		σ_{max}	σ_{min}	$\Delta\sigma$	σ_{max}	σ_{min}	$\Delta\sigma$
DYN1_34	Truck 1, (O.L)	1.6	-0.1	1.7	0.1	-1.5	1.6
	Truck 2, (O.L)	1.5	-0.1	1.6	0.1	-1.3	1.4
	Truck 3, (M.L)	1.3	0.0	1.3	0.0	-1.1	1.1
	Truck 4, (M.L)	1.2	-0.1	1.3	0.1	-1.0	1.1
	Truck 5, (I.L)	1.1	-0.1	1.2	0.1	-1.0	1.1
	Truck 6, (I.L)	1.1	-0.1	1.2	0.1	-0.9	1.0
DYN2_34	Truck 1, (O.L)	1.7	-0.3	2.0	0.3	-1.5	1.8
	Truck 2, (O.L)	1.7	-0.3	2.0	0.3	-1.5	1.8
	Truck 3, (M.L)	1.1	-0.2	1.3	0.2	-1.0	1.2
	Truck 4, (M.L)	1.2	-0.2	1.4	0.3	-1.0	1.3
	Truck 5, (I.L)	1.2	-0.2	1.4	0.1	-0.9	1.0
	Truck 6, (I.L)	1.3	-0.2	1.5	0.2	-1.0	1.2

Table 5.85 – Summary of peak stresses (ksi) measured in strain gages CH_54 and CH_55 installed on the top and bottom flange, respectively, of the east girder in Span 35, approximately 4 in north of midspan as the test trucks crossed over the span in the northbound direction in the dynamic tests

Span 36, top and bottom flange of east girder, 4ft north of midspan							
Test name	Truck in lane	CH_34, (ksi)			CH_33, (ksi)		
		σ_{max}	σ_{min}	$\Delta\sigma$	σ_{max}	σ_{min}	$\Delta\sigma$
DYN1_36	Truck 1, (O.L)	1.6	0.0	1.6	0.0	-0.9	0.9
	Truck 2, (O.L)	1.5	0.0	1.5	0.0	-0.9	0.9
	Truck 3, (M.L)	1.1	0.0	1.1	0.0	-0.7	0.7
	Truck 4, (M.L)	1.1	0.0	1.1	0.0	-0.7	0.7
	Truck 5, (I.L)	1.0	0.0	1.0	0.0	-0.7	0.7
	Truck 6, (I.L)	1.0	0.0	1.0	0.0	-0.7	0.7
DYN2_36	Truck 1, (O.L)	1.6	0.0	1.6	0.8	0.0	0.8
	Truck 2, (O.L)	1.5	0.0	1.5	0.9	0.0	0.9
	Truck 3, (M.L)	1.1	0.0	1.1	0.7	0.0	0.7
	Truck 4, (M.L)	1.1	0.0	1.1	0.7	0.0	0.7
	Truck 5, (I.L)	1.1	0.0	1.1	0.0	-0.6	0.6
	Truck 6, (I.L)	1.1	0.0	1.1	0.0	-0.6	0.6

Table 5.86 – Summary of peak stresses (ksi) measured in strain gages CH_33 and CH_34 installed on the top and bottom flange, respectively, of the east girder in Span 36, approximately 4 in north of midspan as the test trucks crossed over the span in the northbound direction in the dynamic tests

Span 38, top and bottom flange of east girder, 4ft north of midspan							
Test name	Truck in lane	CH_60, (ksi)			CH_59, (ksi)		
		σ_{max}	σ_{min}	$\Delta\sigma$	σ_{max}	σ_{min}	$\Delta\sigma$
DYN1_36	Truck 1, (O.L)	1.5	0.0	1.5	0.0	-1.6	1.6
	Truck 2, (O.L)	1.4	0.0	1.4	0.0	-1.5	1.5
	Truck 3, (M.L)	1.2	0.0	1.2	0.0	-1.3	1.3
	Truck 4, (M.L)	1.1	0.0	1.1	0.0	-1.3	1.3
	Truck 5, (I.L)	0.9	0.0	0.9	0.0	-1.1	1.1
	Truck 6, (I.L)	0.8	0.0	0.8	0.0	-1.0	1.0
DYN2_36	Truck 1, (O.L)	1.4	-0.1	1.5	0.1	-1.6	1.7
	Truck 2, (O.L)	1.4	-0.1	1.5	0.1	-1.6	1.7
	Truck 3, (M.L)	1.2	-0.1	1.3	0.1	-1.3	1.4
	Truck 4, (M.L)	1.1	-0.1	1.2	0.1	-1.3	1.4
	Truck 5, (I.L)	0.8	-0.1	0.9	0.0	-1.1	1.1
	Truck 6, (I.L)	0.8	-0.1	0.9	0.0	-1.0	1.0

Table 5.87 – Summary of peak stresses (ksi) measured in strain gages CH_59 and CH_60 installed on the top and bottom flange, respectively, of the east girder in Span 38, approximately 4 in north of midspan as the test trucks crossed over the span in the northbound direction in the dynamic tests

Span 45, top and bottom flange of east girder, 4ft north of midspan							
Test name	**Truck in lane**	**CH_30, (ksi)**			**CH_29, (ksi)**		
		σ_{max}	σ_{min}	$\Delta\sigma$	σ_{max}	σ_{min}	$\Delta\sigma$
DYN1_45	**Truck 1, (O.L)**	1.7	0.0	1.7	-0.8	0.0	0.8
	Truck 2, (O.L)	1.7	0.0	1.7	-0.8	0.0	0.8
	Truck 3, (M.L)	1.2	0.0	1.2	-0.6	0.0	0.6
	Truck 4, (M.L)	1.3	0.0	1.3	-0.6	0.0	0.6
	Truck 5, (I.L)	1.3	0.0	1.3	-0.6	0.0	0.6
	Truck 6, (I.L)	1.4	0.0	1.4	-0.6	0.0	0.6
DYN2_45	**Truck 1, (O.L)**	1.7	0.0	1.7	-0.8	0.0	0.8
	Truck 2, (O.L)	1.5	-0.2	1.7	-0.8	0.0	0.8
	Truck 3, (M.L)	1.5	-0.1	1.6	-0.7	0.0	0.7
	Truck 4, (M.L)	1.3	-0.1	1.4	-0.7	0.0	0.7
	Truck 5, (I.L)	1.1	-0.2	1.3	-0.6	-0.1	0.7
	Truck 6, (I.L)	1.4	-0.3	1.7	-0.7	-0.1	0.8

Table 5.88 – Summary of peak stresses (ksi) measured in strain gages CH_29 and CH_30 installed on the top and bottom flange, respectively, of the east girder in Span 45, approximately 4 in north of midspan as the test trucks crossed over the span in the northbound direction in the dynamic tests

5.4.2 Stresses in the WT-Section Bolted to Floorbeam Web

Span 35, WT at east girder-to-Floorbeam 2 connection				
Test name	Truck in lane	CH_41, (ksi)		
		σ_{max}	σ_{min}	$\Delta\sigma$
DYN1_34	Truck 1, (O.L)	0.3	-0.2	0.5
	Truck 2, (O.L)	0.1	-0.4	0.5
	Truck 3, (M.L)	0.3	-0.1	0.4
	Truck 4, (M.L)	0.3	-0.1	0.4
	Truck 5, (I.L)	0.2	-0.2	0.4
	Truck 6, (I.L)	0.2	-0.2	0.4
DYN2_34	Truck 1, (O.L)	0.5	-0.1	0.6
	Truck 2, (O.L)	0.6	-0.1	0.7
	Truck 3, (M.L)	0.4	0.0	0.4
	Truck 4, (M.L)	0.4	0.0	0.4
	Truck 5, (I.L)	0.4	-0.1	0.5
	Truck 6, (I.L)	0.3	-0.1	0.4

Table 5.89 – Summary of peak stresses (ksi) measured in strain gage CH_41 installed on the WT of Floorbeam 2 at the floorbeam/east girder intersection and at a distance of approximately 21 1/2” west of the centerline of the east girder and approximately 5 1/2" below the bottom face of the floorbeam top flange in Span 35 (south face of floorbeam web) as the test trucks crossed in the northbound direction over the span in the dynamic tests

Span 36, WT at east girder-to-Floorbeam 8 connection				
Test name	Truck in lane	CH_18, (ksi)		
		σ_{max}	σ_{min}	$\Delta\sigma$
DYN1_36	Truck 1, (O.L)	0.0	-0.2	0.2
	Truck 2, (O.L)	0.0	-0.2	0.2
	Truck 3, (M.L)	0.0	-0.2	0.2
	Truck 4, (M.L)	0.0	-0.1	0.1
	Truck 5, (I.L)	0.0	-0.1	0.1
	Truck 6, (I.L)	0.0	-0.1	0.1
DYN2_36	Truck 1, (O.L)	0.0	-0.2	0.2
	Truck 2, (O.L)	0.0	-0.2	0.2
	Truck 3, (M.L)	0.0	-0.2	0.2
	Truck 4, (M.L)	0.0	-0.2	0.2
	Truck 5, (I.L)	0.0	-0.1	0.1
	Truck 6, (I.L)	0.0	-0.1	0.1

Table 5.90 – Summary of peak stresses (ksi) measured in strain gage CH_18 installed on the WT of Floorbeam 8 bolted to the web of the floorbeam at the floorbeam/east girder intersection and at a distance of approximately 21 1/2” west of the centerline of the east girder and approximately 5 1/2" below the bottom face of the floorbeam top flange in Span 36 (north face of floorbeam web) as the test trucks crossed in the northbound direction over the span in the dynamic tests

Span 45, WT at east girder-to-Floorbeam 2 connection				
Test name	**Truck in lane**	**CH_15, (ksi)**		
		σ_{max}	σ_{min}	$\Delta\sigma$
DYN1_45	**Truck 1, (O.L)**	0.0	-0.2	0.2
	Truck 2, (O.L)	0.1	-0.1	0.2
	Truck 3, (M.L)	0.0	-0.1	0.1
	Truck 4, (M.L)	0.0	-0.1	0.1
	Truck 5, (I.L)	0.0	-0.1	0.1
	Truck 6, (I.L)	0.0	-0.1	0.1
DYN2_45	**Truck 1, (O.L)**	0.0	-0.2	0.2
	Truck 2, (O.L)	0.0	-0.2	0.2
	Truck 3, (M.L)	0.0	-0.1	0.1
	Truck 4, (M.L)	0.0	-0.1	0.1
	Truck 5, (I.L)	0.0	-0.1	0.1
	Truck 6, (I.L)	0.0	-0.1	0.1

Table 5.91 – Summary of peak stresses (ksi) measured in strain gage CH_15 installed on the WT of Floorbeam 2 bolted to the web of the floorbeam at the floorbeam/east girder intersection and at a distance of approximately 21 1/2” west of the centerline of the east girder and approximately 5 1/2" below the bottom face of the floorbeam top flange in Span 36 (north face of floorbeam web) as the test trucks crossed in the northbound direction over the span in the dynamic tests

5.4.3 Stresses in the Riveted Tie Plate

Span 34, east tie plate of Floorbeam 8				
Test name	Truck in lane	CH_12, (ksi)		
		σ_{max}	σ_{min}	$\Delta\sigma$
DYN1_34	Truck 1, (O.L)	1.0	-0.1	1.1
	Truck 2, (O.L)	1.0	-0.4	1.4
	Truck 3, (M.L)	0.4	-0.1	1.4
	Truck 4, (M.L)	0.3	-0.1	1.3
	Truck 5, (I.L)	0.6	-0.1	1.6
	Truck 6, (I.L)	0.5	-0.1	1.5
DYN2_34	Truck 1, (O.L)	1.3	-0.1	1.4
	Truck 2, (O.L)	1.0	-0.3	1.3
	Truck 3, (M.L)	0.3	-0.1	1.3
	Truck 4, (M.L)	0.3	-0.1	1.3
	Truck 5, (I.L)	0.7	-0.1	1.7
	Truck 6, (I.L)	0.7	-0.1	1.7

Table 5.92 – Summary of peak stresses (ksi) measured in strain gage CH_12 installed on the east tie plate of Floorbeam 8 in Span 34 approximately 4 in west to the east girder centerline and 1 in from the edge of the tie plate as the test trucks crossed in the northbound direction over the span in the dynamic tests

Span 35, east tie plate of Floorbeam 2							
Test name	Truck in lane	CH_39, (ksi)			CH_40, (ksi)		
		σ_{max}	σ_{min}	$\Delta\sigma$	σ_{max}	σ_{min}	$\Delta\sigma$
DYN1_34	Truck 1, (O.L)	0.4	-0.7	1.1	1.0	-0.3	1.3
	Truck 2, (O.L)	0.3	-0.6	0.9	0.9	-0.2	1.1
	Truck 3, (M.L)	0.2	-0.7	0.9	0.4	-0.2	0.6
	Truck 4, (M.L)	0.1	-0.6	1.6	0.4	-0.2	0.6
	Truck 5, (I.L)	0.2	-0.5	0.7	0.5	-0.3	0.8
	Truck 6, (I.L)	0.7	-0.5	1	0.5	-0.2	0.7
DYN2_34	Truck 1, (O.L)	0.5	-0.7	1.2	1.2	-0.2	1.4
	Truck 2, (O.L)	0.4	-0.6	1.0	1.2	-0.2	1.4
	Truck 3, (M.L)	0.3	-0.4	0.7	0.6	-0.1	0.7
	Truck 4, (M.L)	0.2	-0.5	0.7	0.6	-0.1	0.7
	Truck 5, (I.L)	0.2	-0.5	0.7	0.5	-0.1	0.6
	Truck 6, (I.L)	0.3	-0.4	0.7	0.6	-0.1	0.7

Table 5.93 – Summary of peak stresses (ksi) measured in strain gages CH_39 and CH_40 installed on the east tie plate of Floorbeam 2 in Span 35 approximately 4 in west to the centerline of the east girder and 1 in from the edge of the tie plate as the test trucks crossed in the northbound direction over the span in the dynamic tests

Span 36, east tie plate of Floorbeam 8							
Test name	Truck in lane	CH_16, (ksi)			CH_17, (ksi)		
		σ_{max}	σ_{min}	$\Delta\sigma$	σ_{max}	σ_{min}	$\Delta\sigma$
DYN1_36	Truck 1, (O.L)	1.0	0.0	1.0	0.8	-0.2	1.0
	Truck 2, (O.L)	1.0	0.0	1.0	0.6	-0.2	0.8
	Truck 3, (M.L)	0.4	0.0	0.4	0.2	-0.2	0.4
	Truck 4, (M.L)	0.3	0.0	0.0	0.3	-0.2	0.5
	Truck 5, (I.L)	0.6	-0.1	0.7	0.7	-0.3	1.0
	Truck 6, (I.L)	0.6	-0.1	0.7	0.7	-0.3	1.0
DYN2_36	Truck 1, (O.L)	1.0	0.0	1.0	0.8	-0.2	1.0
	Truck 2, (O.L)	1.0	0.0	1.0	0.6	-0.2	0.8
	Truck 3, (M.L)	0.4	0.0	0.4	0.2	-0.2	0.4
	Truck 4, (M.L)	0.3	-0.1	0.4	0.2	-0.2	0.4
	Truck 5, (I.L)	0.6	0.0	0.6	0.7	-0.3	1.0
	Truck 6, (I.L)	0.6	-0.1	0.7	0.7	-0.3	1.0

Table 5.94 – Summary of peak stresses (ksi) measured in strain gages CH_16 and CH_17 installed on the east tie plate of Floorbeam 8 at the centerline of the east girder and 1 in from the edge of the tie plate as the test trucks crossed in the northbound direction over the span in the dynamic tests

Span 38, east tie plate of Floorbeam 2							
Test name	Truck in lane	CH_45, (ksi)			CH_46, (ksi)		
		σ_{max}	σ_{min}	$\Delta\sigma$	σ_{max}	σ_{min}	$\Delta\sigma$
DYN1_36	Truck 1, (O.L)	0.8	-0.9	1.7	1.5	-0.2	1.7
	Truck 2, (O.L)	0.8	-0.9	1.7	1.4	-0.2	1.6
	Truck 3, (M.L)	0.1	-0.8	0.9	0.6	-0.2	0.8
	Truck 4, (M.L)	0.1	-0.8	0.9	0.7	-0.2	0.9
	Truck 5, (I.L)	0.2	-0.7	0.9	0.8	-0.1	0.9
	Truck 6, (I.L)	0.2	-0.7	0.9	0.7	-0.2	0.9
DYN2_36	Truck 1, (O.L)	0.8	-0.9	1.7	1.5	-0.2	1.7
	Truck 2, (O.L)	0.8	-0.9	1.7	1.4	-0.3	1.7
	Truck 3, (M.L)	0.1	-0.8	0.9	1.5	-0.2	1.7
	Truck 4, (M.L)	0.1	-0.8	0.9	1.4	-0.3	1.7
	Truck 5, (I.L)	0.2	-0.7	0.9	0.8	-0.1	0.9
	Truck 6, (I.L)	0.2	-0.7	0.9	0.8	-0.2	1.0

Table 5.95 – Summary of peak stresses (ksi) measured in strain gages CH_45 and CH_46 installed on the east tie plate of Floorbeam 2 in Span 38 approximately 4 in west to the centerline of the east girder and 1 in from the edge of the tie plate as the test trucks crossed in the northbound direction over the span in the dynamic tests

Span 45, east tie plate of Floorbeam 2							
Test name	Truck in lane	CH_12, (ksi)			CH_13, (ksi)		
		σ_{max}	σ_{min}	$\Delta\sigma$	σ_{max}	σ_{min}	$\Delta\sigma$
DYN1_45	Truck 1, (O.L)	1.0	-0.3	1.3	1.2	0.0	1.2
	Truck 2, (O.L)	1.0	-0.3	1.3	1.2	0.0	1.2
	Truck 3, (M.L)	0.2	-0.2	0.4	0.4	0.0	0.4
	Truck 4, (M.L)	0.2	-0.3	0.5	0.5	0.0	0.5
	Truck 5, (I.L)	0.4	-0.4	0.8	0.6	0.0	0.6
	Truck 6, (I.L)	0.4	-0.3	0.7	0.7	0.0	0.7
DYN2_45	Truck 1, (O.L)	1.0	-0.4	1.4	1.2	-0.2	1.4
	Truck 2, (O.L)	1.0	-0.3	1.3	1.2	-0.2	1.4
	Truck 3, (M.L)	0.3	-0.3	0.6	0.5	0.0	0.5
	Truck 4, (M.L)	0.3	-0.3	0.6	0.5	0.0	0.5
	Truck 5, (I.L)	0.5	-0.4	0.9	0.7	-0.1	0.8
	Truck 6, (I.L)	0.5	-0.3	0.8	0.6	-0.2	0.8

Table 5.96 – Summary of peak stresses (ksi) measured in strain gages CH_12 and CH_13 installed on the east tie plate of Floorbeam 2 in Span 45 approximately 4 in west to the centerline of the east girder and 1 in from the edge of the tie plate as the test trucks crossed in the northbound direction over the span in the dynamic tests

5.4.4 Stresses in the Web of Prototype Shear Connectors at Cutout Detail

Span 34, south cutout detail on east shear connector at north end of the span							
Test name	Truck in lane	CH_23, (ksi)			CH_24, (ksi)		
		σ_{max}	σ_{min}	$\Delta\sigma$	σ_{max}	σ_{min}	$\Delta\sigma$
DYN1_34	Truck 1, (O.L)	0.7	-0.1	0.8	0.1	-0.7	0.8
	Truck 2, (O.L)	0.6	-0.1	0.7	0.1	-0.6	0.7
	Truck 3, (M.L)	0.9	-0.1	1.0	0.1	-0.9	1.0
	Truck 4, (M.L)	0.8	-0.1	0.9	0.1	-0.9	1.0
	Truck 5, (I.L)	0.4	-0.1	0.5	0.1	-0.4	0.5
	Truck 6, (I.L)	0.5	-0.1	0.6	0.1	-0.5	0.6
DYN2_34	Truck 1, (O.L)	0.3	-0.7	1.0	0.1	-0.8	0.9
	Truck 2, (O.L)	0.4	-0.7	1.1	0.3	-0.9	1.2
	Truck 3, (M.L)	0.2	-0.8	1.0	0.1	-0.9	1.0
	Truck 4, (M.L)	0.2	-0.6	0.8	0.2	-0.7	0.9
	Truck 5, (I.L)	0.3	-0.3	0.6	0.2	-0.4	0.6
	Truck 6, (I.L)	0.3	-0.5	0.8	0.2	-0.5	0.7

Table 5.97 – Summary of peak stresses (ksi) measured in strain gages CH_23 and CH_24 installed back-to-back on the web plate at the south cutout detail (at a vertical distance of approximately 27in from the top face of the top flange) of the east shear connector located at the north end of Span 34 as the test trucks crossed in the northbound direction over the span in the dynamic tests

Span 34, south cutout detail on east shear connector at north end of the span							
Test name	Truck in lane	CH_25, (ksi)			CH_26, (ksi)		
		σ_{max}	σ_{min}	$\Delta\sigma$	σ_{max}	σ_{min}	$\Delta\sigma$
DYN1_34	Truck 1, (O.L)	0.2	-0.5	0.7	0.1	-0.9	1.0
	Truck 2, (O.L)	0.2	-0.5	0.7	0.1	-0.9	1.0
	Truck 3, (M.L)	0.2	-0.5	0.7	0.1	-1.5	1.6
	Truck 4, (M.L)	0.2	-0.5	0.7	0.1	-1.5	1.6
	Truck 5, (I.L)	0.2	-0.3	0.5	0.1	-0.5	0.6
	Truck 6, (I.L)	0.2	-0.4	0.6	0.1	-0.6	0.7
DYN2_34	Truck 1, (O.L)	0.3	-0.6	0.9	0.3	-1.2	1.5
	Truck 2, (O.L)	0.3	-0.6	0.9	0.5	-1.0	1.5
	Truck 3, (M.L)	0.3	-0.6	0.9	0.2	-1.5	1.7
	Truck 4, (M.L)	0.3	-0.5	0.8	0.2	-1.2	1.4
	Truck 5, (I.L)	0.4	-0.4	0.8	0.2	-0.5	0.7
	Truck 6, (I.L)	0.3	-0.5	0.8	0.4	-0.6	1.0

Table 5.98 – Summary of peak stresses (ksi) measured in strain gages CH_25 and CH_26 installed back-to-back on the web plate at the south cutout detail (at a vertical distance of approximately 20 1/2" from the top face of the top flange) of the east shear connector located at the north end of Span 34 as the test trucks crossed in the northbound direction over the span in the dynamic tests

Span 45, south cutout detail on east shear connector at north end of the span							
Test name	Truck in lane	CH_33, (ksi)			CH_34, (ksi)		
		σ_{max}	σ_{min}	$\Delta\sigma$	σ_{max}	σ_{min}	$\Delta\sigma$
DYN1_45	Truck 1, (O.L)	0.4	-3.2	3.6	0.4	-3.3	3.7
	Truck 2, (O.L)	0.2	-3.2	3.4	0.2	-3.4	3.6
	Truck 3, (M.L)	0.0	-4.9	4.9	0.1	-5.0	5.1
	Truck 4, (M.L)	0.2	-4.8	5.0	0.2	-5.2	5.4
	Truck 5, (I.L)	0.1	-2.4	2.5	0.2	-2.5	2.7
	Truck 6, (I.L)	0.1	-2.5	2.6	0.2	-2.6	2.8
DYN2_45	Truck 1, (O.L)	0.6	-3.5	4.1	0.7	-3.8	4.5
	Truck 2, (O.L)	0.6	-3.0	3.6	0.7	-3.2	3.9
	Truck 3, (M.L)	0.2	-4.9	5.2	0.2	-5.0	5.2
	Truck 4, (M.L)	0.3	-4.6	4.9	0.3	-4.9	5.2
	Truck 5, (I.L)	0.4	-2.0	2.4	0.4	-2.0	2.4
	Truck 6, (I.L)	0.7	-2.4	3.1	0.7	-2.5	3.2

Table 5.99 – Summary of peak stresses (ksi) measured in strain gages CH_33 and CH_34 installed back-to-back on the web plate at the south cutout detail (at a vertical distance of approximately 27in from the top face of the top flange) of the east shear connector located at the north end of Span 45 as the test trucks crossed in the northbound direction over the span in the dynamic tests

Span 45, south cutout detail on east shear connector at north end of the span							
Test name	Truck in lane	CH_35, (ksi)			CH_36, (ksi)		
		σ_{max}	σ_{min}	$\Delta\sigma$	σ_{max}	σ_{min}	$\Delta\sigma$
DYN1_45	Truck 1, (O.L)	0.3	-1.4	1.7	0.3	-1.2	1.5
	Truck 2, (O.L)	0.1	-1.5	1.6	0.1	-1.3	1.4
	Truck 3, (M.L)	0.0	-3.1	3.1	0.1	-2.4	2.5
	Truck 4, (M.L)	0.0	-3.0	3.0	0.1	-2.3	2.4
	Truck 5, (I.L)	0.1	-1.1	1.2	0.1	-0.8	1.8
	Truck 6, (I.L)	0.1	-1.2	1.3	0.2	-0.9	2.9
DYN2_45	Truck 1, (O.L)	0.4	-1.6	2.0	0.4	-1.4	1.8
	Truck 2, (O.L)	0.4	-1.5	1.9	0.3	-1.3	1.6
	Truck 3, (M.L)	0.1	-3.1	3.2	0.1	-2.5	2.6
	Truck 4, (M.L)	0.1	-3.0	3.1	0.1	-2.3	2.4
	Truck 5, (I.L)	0.2	-1.0	2.1	0.2	-0.8	1.0
	Truck 6, (I.L)	0.3	-1.1	1.4	0.3	-0.9	1.2

Table 5.100 – Summary of peak stresses (ksi) measured in strain gages CH_35 and CH_36 installed back-to-back on the web plate at the south cutout detail (at a vertical distance of approximately 20 1/2" from the top face of the top flange) of the east shear connector located at the north end of Span 45 as the test trucks crossed in the northbound direction over the span in the dynamic tests

5.4.5 Stresses in the Web of Prototype Shear Connectors near Welded Detail

Span 45, east shear connector web at north end of the span and along weld line				
Test name	Truck in lane	CH_39, (ksi)		
		σ_{max}	σ_{min}	$\Delta\sigma$
DYN1_45	Truck 1, (O.L)	0.3	-0.1	0.4
	Truck 2, (O.L)	0.3	-0.1	0.4
	Truck 3, (M.L)	0.3	0.0	0.3
	Truck 4, (M.L)	0.3	0.0	0.3
	Truck 5, (I.L)	0.2	0.0	0.2
	Truck 6, (I.L)	0.2	0.0	0.2
DYN2_45	Truck 1, (O.L)	0.4	0.0	0.4
	Truck 2, (O.L)	0.4	0.0	0.4
	Truck 3, (M.L)	0.3	0.0	0.3
	Truck 4, (M.L)	0.3	0.0	0.3
	Truck 5, (I.L)	0.2	0.0	0.2
	Truck 6, (I.L)	0.3	0.0	0.3

Table 5.101 – Summary of peak stresses (ksi) measured in strain gage CH_39 installed on the web plate of the east shear connector located at the north end of Span 45 near the north end of the plate and longitudinally along the longitudinal weld used for attaching the shear connector to the bottom face of the deck steel plate in Span 45 as the test trucks crossed in the northbound direction over the span in the dynamic tests

5.4.6 Stresses in the Web of the Prototype Shear Connectors near Bolted Detail

Span 36, on the web plate of the shear connector near the north end of the plate and fit tight with the vertical angle element of the shear connector										
Test name	**Truck in lane**	**CH_5, (ksi)**			**CH_6, (ksi)**			**CH_7, (ksi)**		
		σ_{max}	σ_{min}	$\Delta\sigma$	σ_{max}	σ_{min}	$\Delta\sigma$	σ_{max}	σ_{min}	$\Delta\sigma$
DYN1_36	**Truck 1, (O.L)**	0.0	-0.2	0.2	0.4	-0.1	0.5	0.1	-0.1	0.2
	Truck 2, (O.L)	0.0	-0.2	0.2	0.4	-0.1	0.5	0.1	-0.1	0.2
	Truck 3, (M.L)	0.0	-0.5	0.5	0.2	-.03	0.5	0.3	0.0	0.3
	Truck 4, (M.L)	0.0	-0.6	0.6	0.3	-0.2	0.5	0.3	0.0	0.3
	Truck 5, (I.L)	0.0	-0.1	0.1	0.2	-0.1	0.3	0.0	-0.1	0.1
	Truck 6, (I.L)	0.0	-0.1	0.1	0.2	0.0	0.2	0.0	-0.1	0.1
DYN2_36	**Truck 1, (O.L)**	0.0	-0.2	0.2	0.4	-0.1	0.5	0.1	-0.1	0.2
	Truck 2, (O.L)	0.0	-0.2	0.2	0.4	-0.1	0.5	0.1	-0.1	0.2
	Truck 3, (M.L)	0.0	-0.5	0.5	0.2	-0.3	0.5	0.2	-0.1	0.3
	Truck 4, (M.L)	0.0	-0.6	0.6	0.3	-0.2	0.5	0.3	0.0	0.3
	Truck 5, (I.L)	0.0	-0.1	0.1	0.2	-0.1	0.3	0.0	0.0	0.0
	Truck 6, (I.L)	0.0	-0.1	0.1	0.2	-0.1	0.3	0.0	-0.1	0.1

Table 5.102 – Summary of peak stresses (ksi) measured in strain gages CH_5, CH_6 and CH_7 installed fit tight with the vertical angle element of the shear connector on the north shear connector, at the north end of the span over the east girder and on the west face of the shear connector plate in Span 36 as the test trucks crossed in the northbound direction over the span in the dynamic tests

Span 36, on the web plate of the shear connector near the north end of the plate and fit tight with the vertical angle element of the shear connector										
Test name	Truck in lane	CH_8, (ksi)			CH_9, (ksi)			CH_10, (ksi)		
		σ_{max}	σ_{min}	$\Delta\sigma$	σ_{max}	σ_{min}	$\Delta\sigma$	σ_{max}	σ_{min}	$\Delta\sigma$
DYN1_36	Truck 1, (O.L)	0.1	-0.1	0.2	0.4	-0.1	0.5	0.1	-0.4	0.5
	Truck 2, (O.L)	0.1	-0.1	0.2	0.4	-0.0	0.4	0.0	-0.3	0.3
	Truck 3, (M.L)	0.1	-0.2	0.3	0.3	-0.3	0.6	0.1	-0.2	0.3
	Truck 4, (M.L)	0.1	-0.3	0.4	0.3	-0.3	0.6	0.3	-0.2	0.5
	Truck 5, (I.L)	0.0	0.0	0.0	0.2	-0.1	0.3	0.1	-0.2	0.3
	Truck 6, (I.L)	0.0	0.0	0.0	0.2	-0.1	0.3	0.0	-0.3	0.3
DYN2_36	Truck 1, (O.L)	0.1	-0.1	0.2	0.4	-0.1	0.5	0.0	-0.4	0.4
	Truck 2, (O.L)	0.1	-0.1	0.2	0.4	-0.1	0.5	0.1	-0.3	0.4
	Truck 3, (M.L)	0.1	-0.2	0.3	0.3	-0.3	0.6	0.1	-0.3	0.4
	Truck 4, (M.L)	0.1	-0.3	0.4	0.2	-0.2	0.4	0.3	-0.2	0.5
	Truck 5, (I.L)	0.0	-0.1	0.1	0.2	-0.1	0.3	0.1	-0.2	0.3
	Truck 6, (I.L)	0.1	0.0	0.1	0.2	0.0	0.2	0.0	-0.3	0.3

Table 5.103 – Summary of peak stresses (ksi) measured in strain gages CH_8, CH_9 and CH_10 installed fit tight with the vertical angle element of the shear connector (back-to-back with gages CH_5, CH_6, and CH_7) on the north shear connector, at the north end of the span over the east girder and on the west face of the shear connector plate in Span 36 as the test trucks crossed in the northbound direction over the span in the dynamic tests

Span 45, on the web plate of the shear connector near the north end of the plate and fit tight with the vertical angle element of the shear connector										
Test name	Truck in lane	CH_4, (ksi)			CH_5, (ksi)			CH_6, (ksi)		
		σ_{max}	σ_{min}	$\Delta\sigma$	σ_{max}	σ_{min}	$\Delta\sigma$	σ_{max}	σ_{min}	$\Delta\sigma$
DYN1_45	Truck 1, (O.L)	0.8	0.0	0.8	0.0	-1.3	1.3	0.0	-0.4	0.4
	Truck 2, (O.L)	0.6	0.0	0.6	0.0	-1.4	1.4	0.0	-0.4	0.4
	Truck 3, (M.L)	0.2	-2.8	3.0	0.0	-1.3	1.3	0.0	-0.5	0.5
	Truck 4, (M.L)	0.2	-2.5	2.7	0.0	-1.2	1.2	0.0	-0.5	0.5
	Truck 5, (I.L)	0.2	-0.6	0.8	0.0	-1.1	1.1	0.0	-0.3	0.3
	Truck 6, (I.L)	0.1	-0.8	1.8	0.0	-1.1	1.1	0.0	-0.4	0.4
DYN2_45	Truck 1, (O.L)	0.8	0.0	0.8	0.1	-1.4	1.5	0.0	-0.5	0.5
	Truck 2, (O.L)	0.8	0.0	0.8	0.2	-1.3	1.5	0.0	-0.4	0.4
	Truck 3, (M.L)	0.2	-3.8	4.0	0.0	-1.4	1.4	0.0	-0.7	0.7
	Truck 4, (M.L)	0.2	-3.2	3.4	0.0	-1.3	1.3	0.0	-0.6	0.6
	Truck 5, (I.L)	0.4	-0.9	1.3	0.2	-0.9	1.1	0.1	-0.3	0.4
	Truck 6, (I.L)	0.2	-0.8	1.0	0.2	-1.1	1.3	0.0	-0.3	0.3

Table 5.104 – Summary of peak stresses (ksi) measured in strain gages CH_4, CH_5 and CH_6 installed fit tight with the vertical angle element of the shear connector on the north shear connector, at the north end of the span over the east girder and on the west face of the shear connector plate in Span 45 as the test trucks crossed in the northbound direction over the span in the dynamic tests

Span 45, on the web plate of the shear connector near the north end of the plate and fit tight with the vertical angle element of the shear connector										
Test name	**Truck in lane**	**CH_7, (ksi)**			**CH_8, (ksi)**			**CH_9, (ksi)**		
		σ_{max}	σ_{min}	$\Delta\sigma$	σ_{max}	σ_{min}	$\Delta\sigma$	σ_{max}	σ_{min}	$\Delta\sigma$
DYN1_45	**Truck 1, (O.L)**	0.5	-0.6	1.1	0.0	-0.9	0.9	0.0	-1.0	1.0
	Truck 2, (O.L)	0.5	-0.5	1.0	0.0	-0.9	0.9	0.0	-1.0	1.0
	Truck 3, (M.L)	2.2	0.0	2.2	0.8	-0.7	1.5	0.0	-0.8	0.8
	Truck 4, (M.L)	1.9	0.0	1.9	0.5	-0.7	1.2	0.0	-0.8	0.8
	Truck 5, (I.L)	0.7	0.0	0.7	0.1	-0.7	0.8	0.1	-0.7	1.7
	Truck 6, (I.L)	1.0	0.0	1.0	0.2	-0.8	1.0	0.0	-0.8	0.8
DYN2_45	**Truck 1, (O.L)**	0.6	-0.6	1.2	0.1	-1.0	1.1	0.1	-1.0	1.1
	Truck 2, (O.L)	0.5	-0.5	1.0	0.1	-0.9	1.0	0.2	-1.0	1.2
	Truck 3, (M.L)	3.1	0.0	3.1	0.9	-0.7	1.6	0.0	-0.8	0.8
	Truck 4, (M.L)	2.8	0.0	2.8	0.8	-0.7	1.5	0.0	-0.8	0.8
	Truck 5, (I.L)	1.0	-0.1	1.1	0.1	-0.7	0.8	0.1	-0.6	0.7
	Truck 6, (I.L)	1.0	-0.1	1.1	0.2	-0.7	0.9	0.2	-0.7	0.9

Table 5.105 – Summary of peak stresses (ksi) measured in strain gages CH_7, CH_8 and CH_9 installed fit tight with the vertical angle element of the shear connector (back-to-back with gages CH_6, CH_7, and CH_8) on the north shear connector, at the north end of the span over the east girder and on the west face of the shear connector plate in Span 45 as the test trucks crossed in the northbound direction over the span in the dynamic tests

5.4.7 Stresses in the Standing Angle Bolted to Shear Connector

Span 36, outstanding leg of the south end stiffener angle bolted to the web of the shear connector							
Test name	Truck in lane	CH_3, (ksi)			CH_4, (ksi)		
		σ_{max}	σ_{min}	$\Delta\sigma$	σ_{max}	σ_{min}	$\Delta\sigma$
DYN1_36	Truck 1, (O.L)	0.0	-0.2	0.2	0.0	-0.2	0.2
	Truck 2, (O.L)	0.0	-0.3	0.3	0.0	-0.2	0.2
	Truck 3, (M.L)	0.0	-0.7	0.7	0.1	-0.2	0.3
	Truck 4, (M.L)	0.0	-0.9	0.9	0.3	-0.1	0.4
	Truck 5, (I.L)	0.0	-0.1	0.1	0.0	-0.1	0.1
	Truck 6, (I.L)	0.0	-0.2	0.2	0.0	-0.1	0.1
DYN2_36	Truck 1, (O.L)	0.0	-0.3	0.3	0.0	-0.2	0.2
	Truck 2, (O.L)	0.0	-0.4	0.4	0.0	-0.2	0.2
	Truck 3, (M.L)	0.0	-0.8	0.8	0.1	-0.2	0.3
	Truck 4, (M.L)	0.0	-1.0	1.0	0.2	-0.2	0.4
	Truck 5, (I.L)	0.0	-0.2	0.2	0.0	-0.1	0.1
	Truck 6, (I.L)	0.0	-0.2	0.2	0.0	-0.1	0.1

Table 5.106 – Summary of peak stresses (ksi) measured in strain gages CH_3 and CH_4 back-to-back on the south and north face, respectively, of the outstanding leg of the north end stiffener angle bolted to the web of the shear connector at the north end of the span over the east girder in Span 36 as the test trucks crossed in the northbound direction over the span in the dynamic tests

Span 45, outstanding leg of the south end stiffener angle bolted to the web of the shear connector										
Test name	Truck in lane	CH_10, (ksi)			CH_11, (ksi)			CH_38, (ksi)		
		σ_{max}	σ_{min}	$\Delta\sigma$	σ_{max}	σ_{min}	$\Delta\sigma$	σ_{max}	σ_{min}	$\Delta\sigma$
DYN1_45	Truck 1, (O.L)	0.4	-0.4	0.8	0.4	0.0	0.4	0.3	0.0	0.3
	Truck 2, (O.L)	0.4	-0.4	0.8	0.4	0.0	0.4	0.3	0.0	0.3
	Truck 3, (M.L)	0.8	-0.1	0.9	0.2	-0.5	0.7	0.3	-1.3	1.6
	Truck 4, (M.L)	0.8	-0.3	1.2	0.2	-0.4	0.6	0.3	-1.4	1.7
	Truck 5, (I.L)	0.4	0.0	0.4	0.2	0.0	0.2	0.2	-0.2	0.4
	Truck 6, (I.L)	0.4	0.0	0.4	0.2	0.0	0.2	0.2	-1.2	1.4
DYN2_45	Truck 1, (O.L)	0.5	-0.5	1.0	0.3	-0.1	0.4	0.5	-0.2	0.7
	Truck 2, (O.L)	0.4	-0.4	0.8	0.3	-0.1	0.4	0.4	-0.1	0.5
	Truck 3, (M.L)	1.0	0.0	1.0	0.2	-0.8	1.0	0.0	-1.0	1.0
	Truck 4, (M.L)	1.0	-0.2	1.2	0.2	-0.7	0.9	0.2	-1.3	1.5
	Truck 5, (I.L)	0.4	-0.1	0.5	0.2	0.0	0.2	0.1	-0.3	0.4
	Truck 6, (I.L)	0.4	-0.1	0.5	0.2	0.1	0.3	0.1	-0.4	0.5

Table 5.107 – Summary of peak stresses (ksi) measured in strain gages CH_10, CH_11, and CH_38 installed on the outstanding legs of the north and south end stiffener angles bolted to the web of the shear connector at the north end of the span over the east girder in Span 45 as the test trucks crossed in the northbound direction over the span in the dynamic tests

5.4.8 Stresses in the Deck Plate at the Termination of the Welded and Bolted Shear Connectors

Span 34, transversely on the bottom face of the deck plate at off-center from the shear connector web				
Test name	Truck in lane	CH_28, (ksi)		
		σ_{max}	σ_{min}	$\Delta\sigma$
DYN1_34	Truck 1, (O.L)	0.0	-0.8	0.8
	Truck 2, (O.L)	0.0	-0.8	0.8
	Truck 3, (M.L)	0.0	-1.2	1.2
	Truck 4, (M.L)	0.0	-1.2	1.2
	Truck 5, (I.L)	0.0	-0.5	0.5
	Truck 6, (I.L)	0.0	-0.6	0.6
DYN2_34	Truck 1, (O.L)	-0.2	-0.8	1.0
	Truck 2, (O.L)	-0.2	-0.8	1.0
	Truck 3, (M.L)	-0.2	-1.0	1.2
	Truck 4, (M.L)	-0.2	-1.0	1.2
	Truck 5, (I.L)	-0.2	-0.4	0.6
	Truck 6, (I.L)	-0.2	-0.5	0.7

Table 5.108 – Summary of peak stresses (ksi) measured in strain gages CH_28 installed transversely on the bottom face of the deck plate at 2 in off-center from the shear connector web near the south end of the north shear connector installed in the span over the east girder in Span 34 as the test trucks crossed in the northbound direction over the span in the dynamic tests

Span 34, longitudinally on the bottom face of the deck plate at the termination of the longitudinal shear connector weld				
Test name	**Truck in lane**	**CH_29, (ksi)**		
		σ_{max}	σ_{min}	$\Delta\sigma$
DYN1_34	**Truck 1, (O.L)**	0.1	-0.4	0.5
	Truck 2, (O.L)	0.1	-0.3	0.4
	Truck 3, (M.L)	0.6	-0.3	0.9
	Truck 4, (M.L)	0.6	-0.4	1.0
	Truck 5, (I.L)	0.1	-0.3	0.4
	Truck 6, (I.L)	0.1	-0.3	0.4
DYN2_34	**Truck 1, (O.L)**	0.2	-0.3	0.5
	Truck 2, (O.L)	0.3	-0.3	0.6
	Truck 3, (M.L)	0.6	-0.2	0.8
	Truck 4, (M.L)	0.4	-0.1	0.5
	Truck 5, (I.L)	0.2	-0.2	0.4
	Truck 6, (I.L)	0.2	-0.3	0.5

Table 5.109 – Summary of peak stresses (ksi) measured in strain gages CH_29 installed longitudinally on the bottom face of the deck plate at 1 1/2" from the termination of the longitudinal shear connector weld at the south end of the north shear connector installed over the east girder in Span 34 as the test trucks crossed in the northbound direction over the span in the dynamic tests

Span 36, longitudinally on the bottom face of the deck plate at the termination of the shear connector				
Test name	**Truck in lane**	**CH_2, (ksi)**		
		σ_{max}	σ_{min}	$\Delta\sigma$
DYN1_36	**Truck 1, (O.L)**	0.6	-0.1	0.7
	Truck 2, (O.L)	0.6	-0.1	0.7
	Truck 3, (M.L)	0.4	0.0	0.4
	Truck 4, (M.L)	0.4	0.0	0.4
	Truck 5, (I.L)	0.4	-0.1	0.5
	Truck 6, (I.L)	0.4	-0.1	0.5
DYN2_36	**Truck 1, (O.L)**	0.6	-0.1	0.7
	Truck 2, (O.L)	0.6	-0.2	0.8
	Truck 3, (M.L)	0.4	-0.1	0.5
	Truck 4, (M.L)	0.4	-0.1	0.5
	Truck 5, (I.L)	0.4	-0.1	0.5
	Truck 6, (I.L)	0.4	-0.1	0.5

Table 5.110 – Summary of peak stresses (ksi) measured in strain gages CH_2 installed on the bottom face of the deck plate at the north end termination of the north shear connector located above the east girder in Span 36 as the test trucks crossed in the northbound direction over the span in the dynamic tests

Span 45, transversely on the bottom face of the deck plate at off-center from the shear connector web				
Test name	Truck in lane	CH_32, (ksi)		
		σ_{max}	σ_{min}	$\Delta\sigma$
DYN1_45	Truck 1, (O.L)	0.2	-1.2	1.4
	Truck 2, (O.L)	0.1	-1.2	1.4
	Truck 3, (M.L)	0.0	-1.7	1.7
	Truck 4, (M.L)	0.0	-1.7	1.7
	Truck 5, (I.L)	0.0	-0.8	0.8
	Truck 6, (I.L)	0.0	-1.0	1.0
DYN2_45	Truck 1, (O.L)	0.4	-1.3	1.7
	Truck 2, (O.L)	0.3	-1.2	1.5
	Truck 3, (M.L)	0.1	-1.4	1.5
	Truck 4, (M.L)	0.1	-1.5	1.6
	Truck 5, (I.L)	0.1	-0.7	0.8
	Truck 6, (I.L)	0.2	-0.8	0.9

Table 5.111 – Summary of peak stresses (ksi) measured in strain gages CH_32 installed transversely on the bottom face of the deck plate at 2 in off-center from the shear connector web near the south end of the north shear connector installed over the east girder in Span 45 as the test trucks crossed in the northbound direction over the span in the dynamic tests

Span 45, longitudinally on the bottom face of the deck plate at the termination of the longitudinal shear connector weld				
Test name	**Truck in lane**	**CH_37, (ksi)**		
		σ_{max}	σ_{min}	$\Delta\sigma$
DYN1_45	**Truck 1, (O.L)**	0.0	-0.4	0.4
	Truck 2, (O.L)	0.0	-0.4	0.4
	Truck 3, (M.L)	1.0	-0.5	1.5
	Truck 4, (M.L)	1.0	-0.5	1.5
	Truck 5, (I.L)	0.0	-0.3	0.3
	Truck 6, (I.L)	0.0	-0.3	0.3
DYN2_45	**Truck 1, (O.L)**	0.0	-0.4	0.4
	Truck 2, (O.L)	0.1	-0.3	1.3
	Truck 3, (M.L)	1.0	-0.6	1.6
	Truck 4, (M.L)	0.8	-0.6	1.4
	Truck 5, (I.L)	0.0	-0.3	0.3
	Truck 6, (I.L)	0.0	-0.3	0.3

Table 5.112 – Summary of peak stresses (ksi) measured in strain gages CH_37 installed longitudinally on the bottom face of the deck plate at 1 1/2" from the south termination of longitudinal weld of the north shear connector located at the north end of Span 45 as the test trucks crossed in the northbound direction over the span in the dynamic tests

5.4.9 Stresses in the Web of Existing Sub-floorbeam near Blocked Flange at Sub-floorbeam-to-Stringer Connection

Span 34, web of existing sub-floorbeams near web/flange cutout at sub-floorbeam-to-stringer connection							
Test name	Truck in lane	CH_13, (ksi)			CH_14, (ksi)		
		σ_{max}	σ_{min}	$\Delta\sigma$	σ_{max}	σ_{min}	$\Delta\sigma$
DYN1_34	Truck 1, (O.L)	1.9	-0.2	2.1	--	--	--
	Truck 2, (O.L)	2.2	-0.6	2.8	--	--	--
	Truck 3, (M.L)	0.7	-1.3	2.0	--	--	--
	Truck 4, (M.L)	0.7	-1.4	2.1	--	--	--
	Truck 5, (I.L)	0.5	-0.2	0.7	--	--	--
	Truck 6, (I.L)	0.5	-0.2	0.7	--	--	--
DYN2_34	Truck 1, (O.L)	2.1	0.2	2.3	--	--	--
	Truck 2, (O.L)	2.1	0.3	2.4	--	--	--
	Truck 3, (M.L)	0.7	-1.2	1.8	--	--	--
	Truck 4, (M.L)	0.7	-1.0	1.7	--	--	--
	Truck 5, (I.L)	0.5	-0.2	0.7	--	--	--
	Truck 6, (I.L)	0.5	-0.2	0.7	--	--	--

Note:
"--" indicates significant noise in the data.

Table 5.113 – Summary of peak stresses (ksi) measured in strain gages CH_13 and CH_14 installed horizontally and vertically, respectively, on the south face of the web of Floorbeam 8 and 1 in below the web/flange cutout (between Rib 5 and Stringer 3) in Span 34 as the test trucks crossed in the northbound direction over the span in the dynamic tests

Span 34, web of existing sub-floorbeams near web/flange cutout at sub-floorbeam-to-stringer connection							
Test name	Truck in lane	CH_15, (ksi)			CH_16, (ksi)		
		σ_{max}	σ_{min}	$\Delta\sigma$	σ_{max}	σ_{min}	$\Delta\sigma$
DYN1_34	Truck 1, (O.L)	0.4	-0.1	0.5	0.6	-0.2	0.8
	Truck 2, (O.L)	0.4	-0.1	0.5	0.5	-0.2	0.7
	Truck 3, (M.L)	0.1	-0.2	0.3	0.2	-0.2	0.4
	Truck 4, (M.L)	0.1	-0.2	0.3	0.3	-0.2	0.5
	Truck 5, (I.L)	0.1	-0.2	0.3	0.1	-0.2	0.3
	Truck 6, (I.L)	0.1	-0.2	0.3	0.1	-0.3	0.4
DYN2_34	Truck 1, (O.L)	0.4	-0.3	0.7	0.6	-0.2	0.8
	Truck 2, (O.L)	0.4	-0.3	0.7	0.6	-0.1	0.7
	Truck 3, (M.L)	0.1	-0.1	0.3	0.3	-0.2	0.5
	Truck 4, (M.L)	0.2	-0.1	0.3	0.2	-0.1	0.3
	Truck 5, (I.L)	0.2	-0.2	0.4	0.2	-0.3	0.5
	Truck 6, (I.L)	0.1	-0.3	0.4	0.2	-0.2	0.4

Table 5.114 – Summary of peak stresses (ksi) measured in strain gages CH_15 and CH_16 installed horizontally and vertically, respectively, on the north face of the web of Floorbeam 8 and 1 in below the web/flange cutout (between Rib 5 and Stringer 3) in Span 34 as the test trucks crossed in the northbound direction over the span in the dynamic tests

Span 35, web of existing sub-floorbeams near web/flange cutout at sub-floorbeam-to-stringer connection							
Test name	**Truck in lane**	**CH_44, (ksi)**			**CH_45, (ksi)**		
		σ_{max}	σ_{min}	$\Delta\sigma$	σ_{max}	σ_{min}	$\Delta\sigma$
DYN1_34	**Truck 1, (O.L)**	0.1	0.0	0.1	0.0	-0.4	0.4
	Truck 2, (O.L)	0.0	-0.1	0.1	0.0	-0.3	0.3
	Truck 3, (M.L)	0.0	-0.2	0.2	0.0	-0.2	0.2
	Truck 4, (M.L)	0.0	0.0	0.0	0.0	-0.2	0.2
	Truck 5, (I.L)	0.0	0.0	0.0	0.0	-0.2	0.2
	Truck 6, (I.L)	0.0	0.0	0.0	0.0	-0.2	0.2
DYN2_34	**Truck 1, (O.L)**	0.4	0.0	0.4	0.2	-0.2	0.4
	Truck 2, (O.L)	0.1	0.0	0.1	0.1	-0.3	0.4
	Truck 3, (M.L)	0.1	0.0	0.1	0.2	-0.2	0.4
	Truck 4, (M.L)	0.2	0.0	0.2	0.0	-0.2	0.2
	Truck 5, (I.L)	0.2	0.0	0.2	0.0	-0.1	0.1
	Truck 6, (I.L)	0.1	0.0	0.1	0.0	-0.2	0.2

Table 5.115 – Summary of peak stresses (ksi) measured in strain gages CH_44 and CH_45 installed horizontally and vertically, respectively, on the south face of the web of Floorbeam 2 and at 2 3/4" below the web/flange (between Rib 5 and Stringer 3) in Span 35 as the test trucks crossed in the northbound direction over the span in the dynamic tests

Span 35, web of existing sub-floorbeams near web/flange cutout at sub-floorbeam-to-stringer connection							
Test name	Truck in lane	CH_46, (ksi)			CH_47, (ksi)		
		σ_{max}	σ_{min}	$\Delta\sigma$	σ_{max}	σ_{min}	$\Delta\sigma$
DYN1_34	Truck 1, (O.L)	0.0	0.0	0.0	0.4	-0.2	0.6
	Truck 2, (O.L)	0.0	0.0	0.0	0.4	-0.1	0.5
	Truck 3, (M.L)	0.0	0.0	0.0	0.3	-0.2	0.5
	Truck 4, (M.L)	0.0	0.0	0.0	0.3	-0.2	0.5
	Truck 5, (I.L)	0.0	0.0	0.0	0.2	-0.2	0.4
	Truck 6, (I.L)	0.0	0.0	0.0	0.2	-0.2	0.4
DYN2_34	Truck 1, (O.L)	0.0	0.0	0.0	0.6	-0.1	0.7
	Truck 2, (O.L)	0.0	0.0	0.0	0.6	-0.1	0.7
	Truck 3, (M.L)	0.0	0.0	0.0	0.4	-0.1	0.5
	Truck 4, (M.L)	0.0	0.0	0.0	0.4	-0.1	0.5
	Truck 5, (I.L)	0.0	0.0	0.0	0.5	-0.2	0.7
	Truck 6, (I.L)	0.0	0.0	0.0	0.4	-0.1	0.5

Table 5.116 – Summary of peak stresses (ksi) measured in strain gages CH_46 and CH_47 installed horizontally and vertically, respectively, on the south face of the web of Floorbeam 2 and at 2 3/4" below the web/flange (between Rib5 and Stringer 3) in Span 35 as the test trucks crossed in the northbound direction over the span in the dynamic tests

Span 38, web of existing sub-floorbeams near web/flange cutout at sub-floorbeam-to-stringer connection							
Test name	Truck in lane	CH_48, (ksi)			CH_49, (ksi)		
		σ_{max}	σ_{min}	$\Delta\sigma$	σ_{max}	σ_{min}	$\Delta\sigma$
DYN1_36	Truck 1, (O.L)	0.5	-2.8	3.3	0.4	-0.3	0.7
	Truck 2, (O.L)	0.5	-2.7	3.2	0.4	-0.4	0.8
	Truck 3, (M.L)	0.6	-3.2	3.8	0.4	-0.8	1.2
	Truck 4, (M.L)	0.5	-4.0	4.5	0.4	-1.0	1.4
	Truck 5, (I.L)	0.3	-1.2	1.5	0.5	-0.3	0.8
	Truck 6, (I.L)	0.5	-1.1	1.6	0.4	-0.4	0.8
DYN2_36	Truck 1, (O.L)	0.5	-2.8	3.3	0.4	-0.3	0.7
	Truck 2, (O.L)	0.5	-2.8	3.3	0.4	-0.4	0.8
	Truck 3, (M.L)	0.6	-3.2	3.8	0.4	-0.8	1.2
	Truck 4, (M.L)	0.5	-4.0	4.5	0.3	-1.0	1.3
	Truck 5, (I.L)	0.4	-1.2	1.6	0.5	-0.3	0.8
	Truck 6, (I.L)	0.3	-1.2	1.5	0.4	-0.4	0.8

Table 5.117 – Summary of peak stresses (ksi) measured in strain gages CH_48 and CH_49 installed horizontally and vertically, respectively, on the south face of the web of Floorbeam 2 and 1 in below the web/flange cutout (between Rib 5 and Stringer 3) in Span 38 as the test trucks crossed in the northbound direction over the span in the dynamic tests

Span 38, web of existing sub-floorbeams near web/flange cutout at sub-floorbeam-to-stringer connection							
Test name	Truck in lane	CH_50, (ksi)			CH_51, (ksi)		
		σ_{max}	σ_{min}	$\Delta\sigma$	σ_{max}	σ_{min}	$\Delta\sigma$
DYN1_36	Truck 1, (O.L)	1.2	-1.2	2.4	0.4	-0.8	1.2
	Truck 2, (O.L)	1.1	-1.0	2.1	0.4	-0.8	1.2
	Truck 3, (M.L)	1.0	-1.4	2.4	0.4	-1.4	1.8
	Truck 4, (M.L)	1.2	-1.3	2.5	0.4	-1.8	2.2
	Truck 5, (I.L)	0.9	-0.5	1.4	0.3	-0.4	0.7
	Truck 6, (I.L)	0.8	-0.6	1.4	0.4	-0.4	0.8
DYN2_36	Truck 1, (O.L)	1.2	-1.2	2.4	0.4	-0.8	1.2
	Truck 2, (O.L)	1.1	-1.0	2.1	0.4	-0.8	1.2
	Truck 3, (M.L)	1.0	-1.3	2.3	0.4	-1.4	1.8
	Truck 4, (M.L)	1.2	-1.3	2.5	0.4	-1.8	2.2
	Truck 5, (I.L)	0.9	-0.5	1.4	0.3	-0.4	0.7
	Truck 6, (I.L)	0.8	-0.5	1.3	0.4	-0.4	0.8

Table 5.118 – Summary of peak stresses (ksi) measured in strain gages CH_50 and CH_51 installed horizontally and vertically, respectively, on the north face of the web of Floorbeam 2 and 1 in below the web/flange cutout (between Rib 5 and Stringer 3) in Span 38 as the test trucks crossed in the northbound direction over the span in the dynamic tests

5.4.10 Stresses in the Top and Bottom Flange of New Sub-floorbeam

Span 36, top flange of the welded built-up new prototype sub-Floorbeam 8							
Test name	Truck in lane	CH_20, (ksi)			CH_21, (ksi)		
		σ_{max}	σ_{min}	$\Delta\sigma$	σ_{max}	σ_{min}	$\Delta\sigma$
DYN1_36	Truck 1, (O.L)	1.0	-0.1	1.1	1.2	-0.1	1.3
	Truck 2, (O.L)	1.0	-0.1	1.1	0.9	-0.1	1.0
	Truck 3, (M.L)	0.5	0.0	0.5	0.3	-0.1	0.4
	Truck 4, (M.L)	0.4	0.0	0.4	0.3	-0.1	0.4
	Truck 5, (I.L)	0.1	-0.2	0.3	0.1	-0.2	0.3
	Truck 6, (I.L)	0.0	0.0	0.0	0.0	0.0	0.0
DYN2_36	Truck 1, (O.L)	1.0	-0.1	1.1	1.0	-0.1	1.1
	Truck 2, (O.L)	1.0	-0.1	1.1	0.9	-0.1	1.0
	Truck 3, (M.L)	0.5	-0.1	0.6	0.3	-0.1	0.4
	Truck 4, (M.L)	0.4	-0.1	0.5	0.3	-0.1	0.4
	Truck 5, (I.L)	0.1	-0.2	0.3	0.1	-0.1	0.2
	Truck 6, (I.L)	0.1	-0.2	0.3	0.1	-0.1	0.2

Table 5.119 – Summary of peak stresses (ksi) measured in strain gages CH_20 and CH_21 installed on the top flange (T-section web) of the new Sub-floorbeam 8 west of the web of Stringer 3 and near the south and north end, respectively, of the flange edge at 1 in from the toe of the weld used for attaching the web and the flange of the T-section and at 1 in from the edge of the reduced section of the flange in Span 36 as the test trucks crossed in the northbound direction over the span in the dynamic tests

Span 36, top flange of the welded built-up new prototype Sub-floorbeam 8							
Test name	Truck in lane	CH_22, (ksi)			CH_23, (ksi)		
		σ_{max}	σ_{min}	$\Delta\sigma$	σ_{max}	σ_{min}	$\Delta\sigma$
DYN1_36	Truck 1, (O.L)	0.7	-0.5	1.2	1.0	0.0	1.0
	Truck 2, (O.L)	0.5	-0.5	1.0	0.6	0.0	0.6
	Truck 3, (M.L)	0.9	0.0	0.9	0.5	0.0	0.5
	Truck 4, (M.L)	0.8	0.0	0.8	0.5	0.0	0.5
	Truck 5, (I.L)	0.1	-0.1	0.2	0.3	0.0	0.3
	Truck 6, (I.L)	0.1	-0.1	0.2	0.2	0.0	0.2
DYN2_36	Truck 1, (O.L)	0.7	-0.5	1.2	1.2	0.0	1.2
	Truck 2, (O.L)	0.5	-0.5	1.0	0.7	0.0	0.7
	Truck 3, (M.L)	0.8	-0.1	0.9	0.5	0.0	0.5
	Truck 4, (M.L)	0.7	-0.1	0.8	0.1	0.0	0.1
	Truck 5, (I.L)	0.1	-0.1	0.2	0.0	0.0	0.0
	Truck 6, (I.L)	0.1	-0.1	0.2	0.0	0.0	0.0

Table 5.120 – Summary of peak stresses (ksi) measured in strain gages CH_22 and CH_23 installed on the top flange (T-section web) of the new Sub-floorbeam 8 east of the web of Stringer 3 and near the south and north end, respectively, of the flange edge at 1 in from the toe of the weld used for attaching the web and the flange of the T-section and at 1 in from the edge of the reduced section of the flange in Span 36 as the test trucks crossed in the northbound direction over the span in the dynamic tests

Span 36, bottom cover plate bolted to the bottom flange of the new Sub-floorbeam 8							
Test name	**Truck in lane**	**CH_24, (ksi)**			**CH_25, (ksi)**		
		σ_{max}	σ_{min}	$\Delta\sigma$	σ_{max}	σ_{min}	$\Delta\sigma$
DYN1_36	**Truck 1, (O.L)**	0.0	-0.7	0.7	0.0	-0.6	0.6
	Truck 2, (O.L)	0.0	-0.7	0.7	0.0	-0.7	0.7
	Truck 3, (M.L)	0.0	-0.3	0.3	0.0	-0.5	0.5
	Truck 4, (M.L)	0.0	-0.2	0.2	0.0	-0.5	0.5
	Truck 5, (I.L)	0.0	-0.2	0.2	0.0	-0.3	0.3
	Truck 6, (I.L)	0.0	-0.2	0.2	0.0	-0.3	0.3
DYN2_36	**Truck 1, (O.L)**	0.0	-0.8	0.8	0.0	-0.7	0.7
	Truck 2, (O.L)	0.0	-0.8	0.8	0.0	-0.8	0.8
	Truck 3, (M.L)	0.0	-0.4	0.4	0.1	-0.5	0.6
	Truck 4, (M.L)	0.0	-0.3	0.3	0.1	-0.5	0.6
	Truck 5, (I.L)	0.0	-0.3	0.3	0.0	-0.3	0.3
	Truck 6, (I.L)	0.0	-0.3	0.3	0.0	-0.3	0.3

Table 5.121 – Summary of peak stresses (ksi) measured in strain gages CH_24 and CH_25 bottom cover plate bolted to the bottom flange of new Sub-floorbeam 8 near the south and north edge, respectively, of the cover plate in Span 36 as the test trucks crossed in the northbound direction over the span in the dynamic tests

Span 45, top flange of the welded built-up new prototype Sub-floorbeam 2							
Test name	Truck in lane	CH_21, (ksi)			CH_22, (ksi)		
		σ_{max}	σ_{min}	$\Delta\sigma$	σ_{max}	σ_{min}	$\Delta\sigma$
DYN1_45	Truck 1, (O.L)	0.6	0.0	0.6	0.5	0.0	0.5
	Truck 2, (O.L)	0.5	0.0	0.5	0.4	0.0	0.4
	Truck 3, (M.L)	0.6	0.0	0.6	0.5	0.0	0.5
	Truck 4, (M.L)	0.6	0.0	0.6	0.4	0.0	0.4
	Truck 5, (I.L)	0.0	-0.1	0.1	0.1	0.0	0.1
	Truck 6, (I.L)	0.1	0.0	0.1	0.2	0.0	0.2
DYN2_45	Truck 1, (O.L)	0.7	-0.1	0.8	0.5	-0.1	0.6
	Truck 2, (O.L)	0.6	-0.1	0.7	0.4	-0.1	0.5
	Truck 3, (M.L)	0.5	0.0	0.5	0.7	0.0	0.7
	Truck 4, (M.L)	0.4	0.0	0.4	0.7	0.0	0.7
	Truck 5, (I.L)	0.1	-0.1	0.2	0.1	-0.1	0.2
	Truck 6, (I.L)	0.0	-0.1	0.1	0.1	0.0	0.1

Table 5.122 – Summary of peak stresses (ksi) measured in strain gages CH_21 and CH_22 installed on the top flange (T-section web) of the new Sub-floorbeam 2 west of the web of Stringer 3 and near the south and north end, respectively, of the flange edge at 1 in from the toe of the weld used for attaching the web and the flange of the T-section and at 1 in from the edge of the reduced section of the flange in Span 45 as the test trucks crossed in the northbound direction over the span in the dynamic tests

Span 45, top flange of the welded built-up new prototype Sub-floorbeam 8							
Test name	Truck in lane	CH_19, (ksi)			CH_20, (ksi)		
		σ_{max}	σ_{min}	$\Delta\sigma$	σ_{max}	σ_{min}	$\Delta\sigma$
DYN1_45	Truck 1, (O.L)	0.7	-0.1	0.8	1.4	-0.1	1.5
	Truck 2, (O.L)	0.6	-0.1	0.7	1.2	-0.1	1.3
	Truck 3, (M.L)	0.4	-0.1	0.5	0.8	-0.1	0.9
	Truck 4, (M.L)	0.4	-0.1	0.5	0.8	-0.1	0.9
	Truck 5, (I.L)	0.1	-0.1	0.2	0.1	-0.1	0.2
	Truck 6, (I.L)	0.1	-0.1	0.2	0.2	-0.1	0.3
DYN2_45	Truck 1, (O.L)	0.7	-0.2	0.9	1.2	-0.2	1.4
	Truck 2, (O.L)	0.6	-0.2	0.8	1.2	-0.1	1.3
	Truck 3, (M.L)	0.5	0.0	0.5	1.0	-0.1	1.1
	Truck 4, (M.L)	0.4	-0.1	0.5	1.1	-0.2	1.3
	Truck 5, (I.L)	0.1	-0.1	0.2	0.1	-0.2	0.3
	Truck 6, (I.L)	0.1	-0.1	0.2	0.1	-0.1	0.2

Table 5.123 – Summary of peak stresses (ksi) measured in strain gages CH_19 and CH_20 installed on the top flange (T-section web) of the new Sub-floorbeam 2 east of the web of Stringer 3 and near the south and north end, respectively, of the flange edge at 1 in from the toe of the weld used for attaching the web and the flange of the T-section and at 1 in from the edge of the reduced section of the flange in Span 45 as the test trucks crossed in the northbound direction over the span in the dynamic tests

5.4.11 Stresses in the Orthotropic Rib Web Plate

Span 35, west web plate of Rib 6							
Test name	Truck in lane	CH_50, (ksi)			CH_51, (ksi)		
		σ_{max}	σ_{min}	$\Delta\sigma$	σ_{max}	σ_{min}	$\Delta\sigma$
DYN1_34	Truck 1, (O.L)	0.0	0.0	0.0	0.0	0.0	0.0
	Truck 2, (O.L)	0.0	0.0	0.0	0.0	0.0	0.0
	Truck 3, (M.L)	0.0	0.0	0.0	0.4	-0.4	0.8
	Truck 4, (M.L)	0.0	0.0	0.0	0.3	-0.2	0.5
	Truck 5, (I.L)	0.0	0.0	0.0	0.0	0.0	0.0
	Truck 6, (I.L)	0.0	0.0	0.0	0.0	0.0	0.0
DYN2_34	Truck 1, (O.L)	0.0	0.0	0.0	0.0	0.0	0.0
	Truck 2, (O.L)	0.0	0.0	0.0	0.0	0.0	0.0
	Truck 3, (M.L)	0.0	0.0	0.0	0.2	-0.9	1.1
	Truck 4, (M.L)	0.0	0.0	0.0	0.4	-0.4	0.8
	Truck 5, (I.L)	0.0	0.0	0.0	0.0	0.0	0.0
	Truck 6, (I.L)	0.0	0.0	0.0	0.0	0.0	0.0

Table 5.124 – Summary of peak stresses (ksi) measured in strain gages CH_50 and CH_51 installed on the west web plate of Rib 6 (south west and north west of the plate, respectively) at 2 in vertically from the bottom flange of the rib and approximately 4 1/2" apart longitudinally (off of the centerline of the sub-floorbeam flange) in Span 35 as the test trucks crossed in the northbound direction over the span in the dynamic tests

Span 35, east web plate of Rib 6							
Test name	Truck in lane	CH_52, (ksi)			CH_53, (ksi)		
		σ_{max}	σ_{min}	$\Delta\sigma$	σ_{max}	σ_{min}	$\Delta\sigma$
DYN1_34	Truck 1, (O.L)	0.0	0.0	0.0	0.0	0.0	0.0
	Truck 2, (O.L)	0.0	0.0	0.0	0.0	0.0	0.0
	Truck 3, (M.L)	0.3	-0.6	0.9	0.2	-0.9	1.1
	Truck 4, (M.L)	0.2	-0.5	0.7	0.2	-0.5	0.7
	Truck 5, (I.L)	0.0	0.0	0.0	0.0	0.0	0.0
	Truck 6, (I.L)	0.0	0.0	0.0	0.0	0.0	0.0
DYN2_34	Truck 1, (O.L)	0.0	0.0	0.0	0.0	0.0	0.0
	Truck 2, (O.L)	0.0	0.0	0.0	0.0	0.0	0.0
	Truck 3, (M.L)	0.3	-0.7	1.0	0.4	-0.9	1.3
	Truck 4, (M.L)	0.4	-0.6	1.0	0.4	-0.9	1.3
	Truck 5, (I.L)	0.0	0.0	0.0	0.0	0.0	0.0
	Truck 6, (I.L)	0.0	0.0	0.0	0.0	0.0	0.0

Table 5.125 – Summary of peak stresses (ksi) measured in strain gages CH_52 and CH_53 installed on the east web plate of Rib 6 (south east and north east of the plate, respectively) at 2 in vertically from the bottom flange of the rib and approximately 4 1/2" apart longitudinally (off of the centerline of the sub-floorbeam flange) in Span 35 as the test trucks crossed in the northbound direction over the span in the dynamic tests

Span 36, west web plate of Rib 6							
Test name	Truck in lane	CH_28, (ksi)			CH_30, (ksi)		
		σ_{max}	σ_{min}	$\Delta\sigma$	σ_{max}	σ_{min}	$\Delta\sigma$
DYN1_36	Truck 1, (O.L)	0.2	-0.1	0.3	0.3	-0.1	0.4
	Truck 2, (O.L)	0.2	-0.1	0.3	0.3	-0.1	0.4
	Truck 3, (M.L)	0.1	-0.6	0.7	1.0	-0.5	1.5
	Truck 4, (M.L)	0.1	-0.7	0.8	0.9	-0.6	1.5
	Truck 5, (I.L)	0.1	-0.2	0.3	0.2	-0.1	0.3
	Truck 6, (I.L)	0.1	-0.1	0.2	0.1	-0.1	0.2
DYN2_36	Truck 1, (O.L)	0.2	-0.1	0.3	0.3	-0.1	0.4
	Truck 2, (O.L)	0.2	-0.1	0.3	0.3	-0.1	0.4
	Truck 3, (M.L)	0.1	-0.6	0.7	0.9	-0.5	1.4
	Truck 4, (M.L)	0.1	-0.7	0.8	0.9	-0.6	1.5
	Truck 5, (I.L)	0.1	-0.2	0.3	0.2	-0.1	0.3
	Truck 6, (I.L)	0.1	-0.1	0.2	0.1	-0.1	0.2

Table 5.126 – Summary of peak stresses (ksi) measured in strain gages CH_28 and CH_30 installed on the west web plate of Rib 6 (south west and north west of the plate, respectively) at 2 in vertically from the bottom flange of the rib and approximately 4 1/2” apart longitudinally (off of the centerline of the sub-floorbeam flange) in Span 36 as the test trucks crossed in the northbound direction over the span in the dynamic tests

Span 36, east web plate of Rib 6							
Test name	**Truck in lane**	**CH_29, (ksi)**			**CH_31, (ksi)**		
		σ_{max}	σ_{min}	$\Delta\sigma$	σ_{max}	σ_{min}	$\Delta\sigma$
DYN1_36	**Truck 1, (O.L)**	0.1	-0.1	0.2	0.2	0.0	0.2
	Truck 2, (O.L)	0.1	-0.1	0.2	0.2	0.0	0.2
	Truck 3, (M.L)	0.2	0.7	0.9	0.6	-0.4	1.0
	Truck 4, (M.L)	0.3	0.7	1.0	0.7	-0.4	1.1
	Truck 5, (I.L)	0.1	-0.1	0.2	0.1	-0.1	0.2
	Truck 6, (I.L)	0.1	-0.1	0.2	0.1	-0.1	0.2
DYN2_36	**Truck 1, (O.L)**	0.1	-0.1	0.2	0.2	0.0	0.2
	Truck 2, (O.L)	0.1	-0.1	0.2	0.2	0.0	0.2
	Truck 3, (M.L)	0.2	-0.7	0.9	0.6	-0.4	1.0
	Truck 4, (M.L)	0.2	-0.7	0.9	0.7	-0.4	1.1
	Truck 5, (I.L)	0.8	-0.1	0.9	0.1	-0.1	0.2
	Truck 6, (I.L)	0.9	-0.1	1.0	0.1	-0.1	0.2

Table 5.127 – Summary of peak stresses (ksi) measured in strain gages CH_29 and CH_31 installed on the east web plate of Rib 6 (south east and north east of the plate, respectively) at 2 in vertically from the bottom flange of the rib and approximately 4 1/2" apart longitudinally (off of the centerline of the sub-floorbeam flange) in Span 36 as the test trucks crossed in the northbound direction over the span in the dynamic tests

Span 38, west web plate of Rib 6							
Test name	Truck in lane	CH_55, (ksi)			CH_56, (ksi)		
		σ_{max}	σ_{min}	$\Delta\sigma$	σ_{max}	σ_{min}	$\Delta\sigma$
DYN1_36	Truck 1, (O.L)	0.1	-0.1	0.2	0.0	-0.1	0.1
	Truck 2, (O.L)	0.0	-0.1	0.1	0.0	-0.1	0.1
	Truck 3, (M.L)	0.3	-0.3	0.6	0.4	-0.4	0.8
	Truck 4, (M.L)	0.2	-1.0	1.2	0.3	-0.9	1.2
	Truck 5, (I.L)	0.0	-0.1	0.1	0.0	-0.1	0.1
	Truck 6, (I.L)	0.0	-0.1	0.1	0.0	-0.1	0.1
DYN2_36	Truck 1, (O.L)	0.1	-0.1	0.2	0.1	-0.1	0.2
	Truck 2, (O.L)	0.1	-0.1	0.2	0.1	-0.1	0.2
	Truck 3, (M.L)	0.3	-0.3	0.6	0.4	-0.4	0.8
	Truck 4, (M.L)	0.2	-1.0	1.2	0.3	-1.0	1.3
	Truck 5, (I.L)	0.0	-0.1	0.1	0.0	-0.1	0.1
	Truck 6, (I.L)	0.0	-0.1	0.1	0.0	-0.1	0.1

Table 5.128 – Summary of peak stresses (ksi) measured in strain gages CH_55 and CH_56 installed on the west web plate of Rib 6 (south west and north west of the plate, respectively) at 2 in vertically from the bottom flange of the rib and approximately 4 1/2" apart longitudinally (off of the centerline of the sub-floorbeam flange) in Span 38 as the test trucks crossed in the northbound direction over the span in the dynamic tests

Span 38, east web plate of Rib 6							
Test name	Truck in lane	CH_58, (ksi)			CH_57, (ksi)		
		σ_{max}	σ_{min}	$\Delta\sigma$	σ_{max}	σ_{min}	$\Delta\sigma$
DYN1_36	Truck 1, (O.L)	0.0	-0.1	0.1	0.0	-0.1	0.1
	Truck 2, (O.L)	0.0	-0.1	0.1	0.0	-0.1	0.1
	Truck 3, (M.L)	0.2	-0.8	1.0	0.3	-0.8	1.1
	Truck 4, (M.L)	0.3	-0.9	1.2	0.4	-0.9	1.3
	Truck 5, (I.L)	0.0	0.0	0.0	0.0	0.0	0.0
	Truck 6, (I.L)	0.0	0.0	0.0	0.0	0.0	0.0
DYN2_36	Truck 1, (O.L)	0.0	-0.2	0.2	0.0	-0.2	0.2
	Truck 2, (O.L)	0.0	-0.2	0.2	0.0	-0.1	0.1
	Truck 3, (M.L)	0.2	-0.8	1.0	0.3	-0.8	1.2
	Truck 4, (M.L)	0.3	-0.9	1.2	0.4	-0.9	1.3
	Truck 5, (I.L)	0.0	0.0	0.0	0.0	0.0	0.0
	Truck 6, (I.L)	0.0	0.0	0.0	0.0	0.0	0.0

Table 5.129 – Summary of peak stresses (ksi) measured in strain gages CH_58 and CH_57 installed on the east web plate of Rib 6 (south east and north east of the plate, respectively) at 2 in vertically from the bottom flange of the rib and approximately 4 1/2" apart longitudinally (off of the centerline of the sub-floorbeam flange) in Span 38 as the test trucks crossed in the northbound direction over the span in the dynamic tests

Span 45, west web plate of Rib 6							
Test name	Truck in lane	CH_25, (ksi)			CH_27, (ksi)		
		σ_{max}	σ_{min}	$\Delta\sigma$	σ_{max}	σ_{min}	$\Delta\sigma$
DYN1_45	Truck 1, (O.L)	0.4	0.0	0.4	0.1	-0.1	0.2
	Truck 2, (O.L)	0.3	0.0	0.3	0.1	-0.1	0.2
	Truck 3, (M.L)	0.5	-0.8	1.3	0.1	-0.7	0.8
	Truck 4, (M.L)	0.5	-0.6	1.1	0.1	-0.6	0.7
	Truck 5, (I.L)	0.2	-0.1	0.3	0.1	-0.1	0.2
	Truck 6, (I.L)	0.2	-0.4	0.6	0.1	-0.3	0.4
DYN2_45	Truck 1, (O.L)	0.4	0.0	0.4	0.2	0.0	0.2
	Truck 2, (O.L)	0.3	-0.1	0.4	0.1	-0.1	0.2
	Truck 3, (M.L)	0.6	-1.0	1.6	0.2	-0.7	0.9
	Truck 4, (M.L)	0.6	-0.7	1.3	0.1	-0.4	0.5
	Truck 5, (I.L)	0.2	-0.2	0.4	0.1	-0.2	0.3
	Truck 6, (I.L)	0.2	-0.2	0.4	0.1	-0.2	0.3

Table 5.130 – Summary of peak stresses (ksi) measured in strain gages CH_25 and CH_27 installed on the west web plate of Rib 6 (south west and north west of the plate, respectively) at 2 in vertically from the bottom flange of the rib and approximately 4 1/2" apart longitudinally (off of the centerline of the sub-floorbeam flange) in span 45 as the test trucks crossed in the northbound direction over the span in the dynamic tests

Span 45, east web plate of Rib 6							
Test name	**Truck in lane**	**CH_26, (ksi)**			**CH_28, (ksi)**		
		σ_{max}	σ_{min}	$\Delta\sigma$	σ_{max}	σ_{min}	$\Delta\sigma$
DYN1_45	**Truck 1, (O.L)**	0.2	0.0	0.2	0.1	-0.2	0.3
	Truck 2, (O.L)	0.2	0.0	0.2	0.1	-0.2	0.3
	Truck 3, (M.L)	0.5	-1.0	1.5	0.4	-1.4	1.8
	Truck 4, (M.L)	0.5	-1.0	1.5	0.4	-1.4	1.8
	Truck 5, (I.L)	0.2	0.0	0.2	0.1	0.0	0.1
	Truck 6, (I.L)	0.5	-0.	0.5	0.3	-0.3	0.6
DYN2_45	**Truck 1, (O.L)**	0.3	0.0	0.3	0.1	-0.2	0.3
	Truck 2, (O.L)	0.2	-0.1	0.3	0.1	-0.1	0.2
	Truck 3, (M.L)	0.6	-1.0	1.6	0.6	-1.1	1.7
	Truck 4, (M.L)	0.6	-1.2	1.8	0.6	-1.1	1.7
	Truck 5, (I.L)	0.3	0.0	0.3	0.1	0.0	0.1
	Truck 6, (I.L)	0.3	0.0	0.3	0.2	0.0	0.2

Table 5.131 – Summary of peak stresses (ksi) measured in strain gages CH_26 and CH_28 installed on the east web plate of Rib 6 (south east and north east of the plate, respectively) at 2 in vertically from the bottom flange of the rib and approximately 4 1/2” apart longitudinally (off of the centerline of the sub-floorbeam flange) in Span 45 as the test trucks crossed in the northbound direction over the span in the dynamic tests

5.5 Analysis of Acceleration Data

5.5.1 Numerical Integration

The acceleration time-history records can be integrated twice determine displacement time-histories. Integration of an acceleration record yields a velocity time-history. After integrating this velocity time-history, a displacement time-history is obtained. The numerical integration is performed using the trapezoidal rule, as shown below:

$$v_{i+1} = \frac{1}{2}(\Delta t)(a_{i+1} + a_i) + v_i \qquad \text{Eqn. 1.1}$$

$$d_{i+1} = \frac{1}{2}(\Delta t)(v_{i+1} + v_i) + d_i \qquad \text{Eqn. 1.2}$$

where:

a = acceleration
v = velocity
d = displacement
Δt = time step

When the numerical integration is performed, any low frequency noise present in the data (such as a non-zero offset or low frequency drift) will lead to large errors and drift in the resulting time-history. In order to alleviate this problem, the data must be filtered prior to each integration. A high pass filter is used to remove low frequency noise while preserving the higher frequency content.

The cutoff frequency for the filter must be selected such that it is high enough to remove unwanted low-frequency noise, but low enough such that it does not compromise data at the frequencies of interest. Generally, when the loading frequency is less than 0.5 Hz, numerical integration is difficult to use.

The frequency of loading of the test truck during the crawl tests was very low, on the order of 0.02 Hz (the truck crossed each span in about 50 seconds). Therefore, this proposed use of numerical integration is not applicable for these tests.

The frequency of loading of the test truck during the dynamic tests was larger, on the order of 0.35 Hz (the truck crossed each span in about 2.9 seconds). Though the frequency of loading is still low, it was decided to perform the numerical integrations and then evaluate the results.

5.5.2 Analysis Procedure

The procedure for obtaining the displacement time-histories is described in detail in this section. All data manipulation was performed in the MATLAB environment.

1. *Decimate the data* - The data were originally sampled at 250 Hz. Prior to numerical integration, the data were decimated by 10 to yield 25 Hz data.
2. *Filter the acceleration time-history* – The acceleration time-history is filtered using a 6-pole Type 1 Chebyshev filter with a cutoff frequency of 0.2 Hz. A zero-phase filtering algorithm was used to minimize start-up and ending transients in the data.

3. *Integrate the acceleration time-history* – The acceleration time-history is integrated using the trapezoidal rule described above to obtain a velocity time-history.
4. *Filter the velocity time-history* – The velocity time-history is filtered using the same parameters in Step 2.
5. *Integrate the velocity time-history* – The velocity time-history is integrated using the trapezoidal rule described above to obtain a displacement time-history.
6. *Filter the displacement time-history* – The displacement time-history is filtered using the same parameters in Step 2, to obtain a final displacement time-history.

5.5.3 Results of Acceleration Measurements

Data from the dynamic tests DYN2 were selected for analysis. During these tests, the test trucks were driven across the bridge at a speed of approximately 50 mph. This higher test speed maximizes the loading frequency which will improve the quality of the calculated displacement time-histories.

Unfortunately, the loading frequency was not sufficiently high. Figure 5.22 contains an example of an acceleration time history in span 34 during test DYN2. The six peaks shown in the figure represent the passage of Truck 1 in the right lane (first peak), followed by Truck 2 in the same lane (second peak), followed by Truck 3 in the middle lane (third peak), followed by Truck 4 also in the middle lane (fourth peak), followed by Truck 5 in the left lane (fifth peak), and finally Truck 6 also in the left lane (sixth peak). The filtered acceleration record is contained in the top of the figure. The peak acceleration was approximately 0.06 g and was produced by the crossing of the crossing of Truck 2 in the outside lane (second peak in the figure).

In the second plot of the same figure, the calculated velocity time history is presented. The peak calculated velocity is approximately 1.5 in/sec. Finally, the bottom of Figure 5.22 shows the calculated displacement history. A peak displacement of only 0.15 inches is shown. Shown in Figure 5.23 is a detail view of the crossing of the second truck (indicated by the dashed lines in Figure 5.22. It can be seen that the majority of the displacement is the result of vibration of the bridge span in its first mode of vibration at a frequency of 2.34 Hz caused by the excitation of the test truck. There appears to be little low frequency displacement that would be representative of the global displacement of the girder under load.

It is most likely that the primary displacement caused by the presence of the truck above occurs with a frequency of 0.2 Hz or less and is therefore lost during the filtering operation. The magnitudes of the acceleration are too small to measure and subsequently integrate.

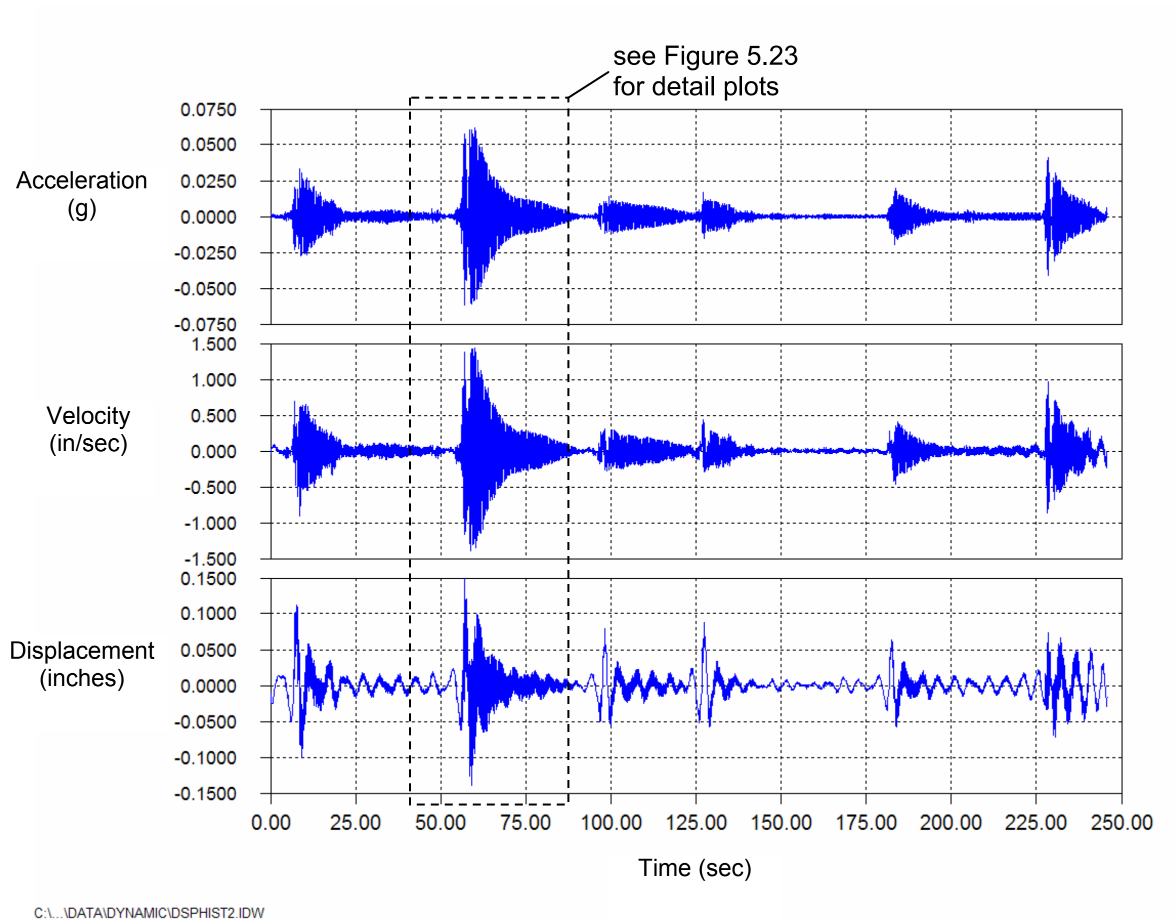


Figure 5.22– Acceleration, velocity, and displacement records for span 34 during test DYN2

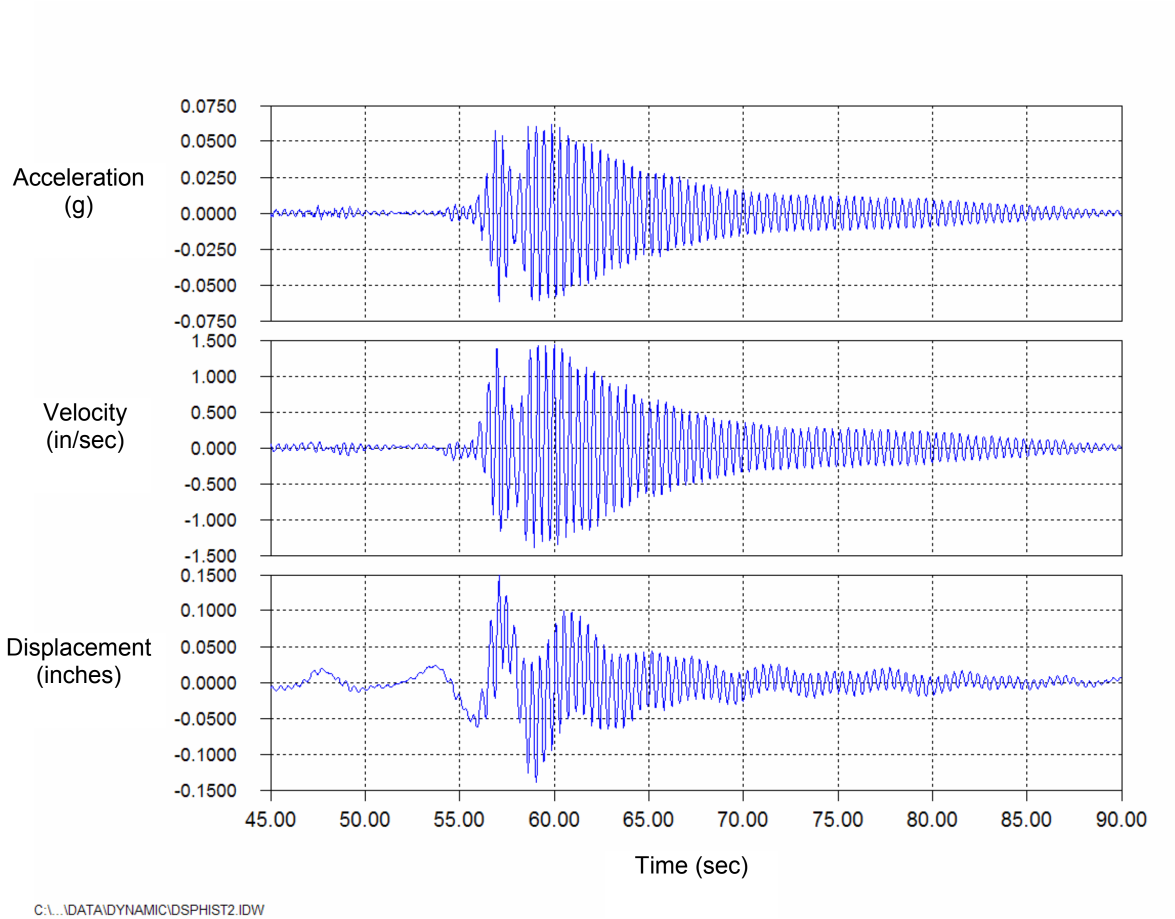


Figure 5.23– Detail of acceleration, velocity, and displacement records for span 34 during test DYN2

6.0 Long-term Monitoring

All channels installed on all five spans, including strain gages, displacement sensors, accelerometers, and thermocouples were chosen for long-term monitoring. Long-term monitoring was conducted from August 25, 2005 through October 17, 2005, prior to the TN overload weight restriction which started in the month of November. Monitoring was disrupted by some uncontrollable events (loss of electric power, etc.), which resulted in Span 34 and Span 35 being monitored for a total period of approximately 44 days, Span 36 and Span 38 being monitored for a total period of approximately 39 days, and Span 45 being monitored for a total period of approximately 50 days. Our experience with field monitoring indicates that a minimum monitoring period of one month is needed for proper presentation of actual traffic on the bridge.

The long-term data consists in part of triggered time-history data in which recording of the data in Spans 34 and 35 commenced when a predefined stress value was measured in strain gages CH_5 or CH_55, respectively, installed on the bottom flange of the east girder. Similarly, in Spans 36 and 38, recording of the data began when a predefined stress value was measured in strain gages CH_34 or CH_60, respectively, installed on the bottom flange of the east girder. Finally, in Span 45 recording of the data was triggered when a predefined stress value was measured in strain gage CH_30 installed on the bottom flange of the east girder. For every trigger event, eight seconds of data prior to the event and eight seconds after the event were recorded.

In addition to the recorded triggered events, stress-range histograms, <u>only</u> for the strain gages, were generated by the data logger using the rainflow cycle counting algorithm *(the non-truncated histograms are listed in Appendix C)*. The stress-range histograms were later used for estimating the remaining fatigue life of the applicable instrumented details. It is important to note that such estimates were conducted assuming the data is representative of the stress-history during the life of the bridge (i.e., constant traffic volume and pattern since the bridge opened to traffic). An increase in the traffic volume and pattern on the bridge could result in lower remaining fatigue life than what is estimated.

When strain gage data for a certain period of time was questionable (i.e., the data appear to have significant noise, or the strain gage appears to have malfunctioned), the part of the questionable data from that strain gage was disregarded and not used in the fatigue life estimates of the detail. For example, although the total monitoring period of the strain gages installed in Span 34 and Span 35 was approximately 44 days as indicated above, only 30 days worth of data were used for calculating the remaining life of the detail where strain gage CH_24 was installed in Span34.

6.1 Results of Long-term Monitoring

An estimate of the magnitude of the stresses caused by the normal daily traffic was established from the triggered time-history data as well as the stress-range histogram data collected during the long-term monitoring period. Stresses of higher magnitude than those produced by the test truck(s) were observed at some locations as presented in the histograms below.

6.2 Stress-Range Histograms

6.2.1 Stresses in the Riveted Main East Girder Flange

As previously discussed, to monitor the response of the riveted main girders to a random moving load, strain gages were installed on top and bottom flange of the east girder at or near mid span in all five spans. Specifically, strain gages CH_4, CH_54, CH_33, CH_59, and CH_29 were installed at mid width of the top flange of the east girders in Span 34, Span 35, Span 36, Span 38, and Span 45, respectively, and strain gages CH_5, CH_55, CH_34, and CH_30 were installed at mid width of the bottom flange of the east girders in Span 34, Span 35, Span 36, and Span 45, respectively. Because of accessibility, strain gage CH_60 was installed on the top face of the bottom flange at approximately 1 in from the edge of the flange. The gages were installed on the girders at 4 ft north of mid span of the girder.

During the monitoring period it was observed, when viewing the data, that the vibration of the girder is rather random. Figure 6.1 is an example of the response of strain gages CH_5 during two triggered time-history events. As shown in the figure, the magnitude of the peak response in both events is very similar (i.e., 3.0 ksi in the first event and 2.7 ksi in the second event). However, in the first event, the girder underwent excessive vibration, while no vibration was observed in the second event. Such observation is not consistent with the results of the dynamic controlled load tests as dynamic vibration of the girder was observed during each dynamic test. This could be due to the orthotropic deck system being light in weight such that its interaction with vehicles crossing the bridge is always varying (depending on vehicle type, suspension system of the vehicle, etc.). The excessive vibration of the girder during the random monitoring could result in a dynamic amplification factor of the girder being higher than what is observed during the controlled load test.

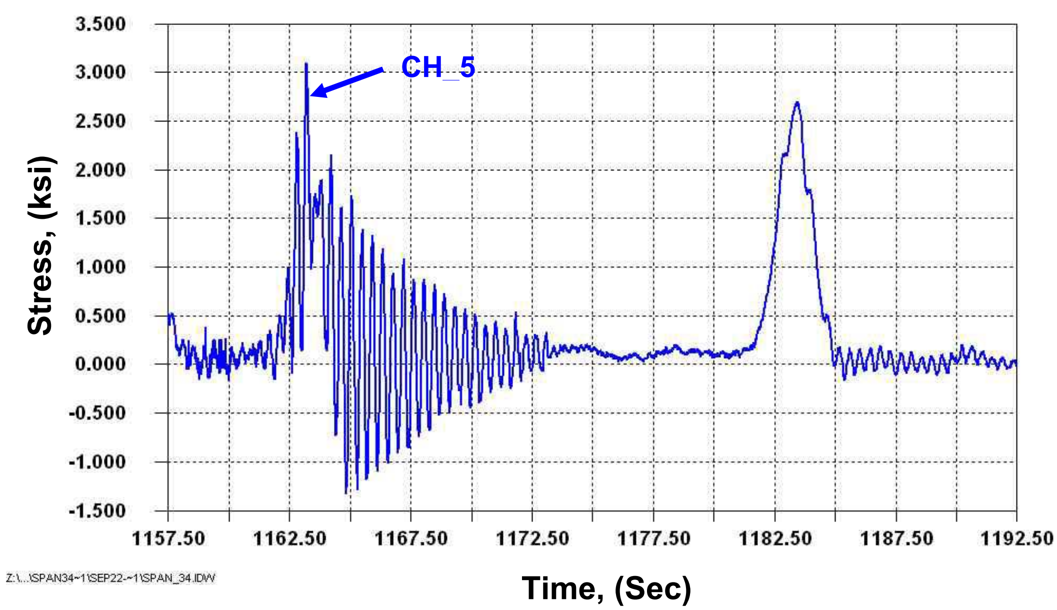


Figure 6.1 – Random time-history response of strain gage CH_5 installed on the bottom flange of the east girder in Span 34, approximately 4 in north of midspan

The detail is classified as Category D detail per AASHTO Specifications with a constant amplitude fatigue limit (CAFL) of 7 ksi. No stress-range cycles higher than the CAFL of the detail were measured at any of the instrumented locations during the monitoring period. The highest magnitude of stress range measured was 6.3 ksi and was recorded by strain gages CH_5 and CH_55 installed on the bottom flange of the east girder in Span 34 and Span 35, respectively. Figure 6.2 shows the stress-range histogram for strain gage CH_5 and strain gage CH_55. The inset in the figure is a magnification of the right-most portion of the histogram. The histogram was produced using a lower-bound stress range truncation level of 1.75 ksi, which is approximately 1/4 of the CAFL of the detail. More detailed discussion on truncation levels used in fatigue evaluations can be found in Appendix B. A summary of the magnitude of the maximum stress range, effective stress range, number of cycles measured per day, and the estimated remaining fatigue life for the instrumented details is presented in Table 6.1. As can be seen in the table, the fatigue life calculations indicate an infinite remaining life for all four instrumented east riveted girders details.

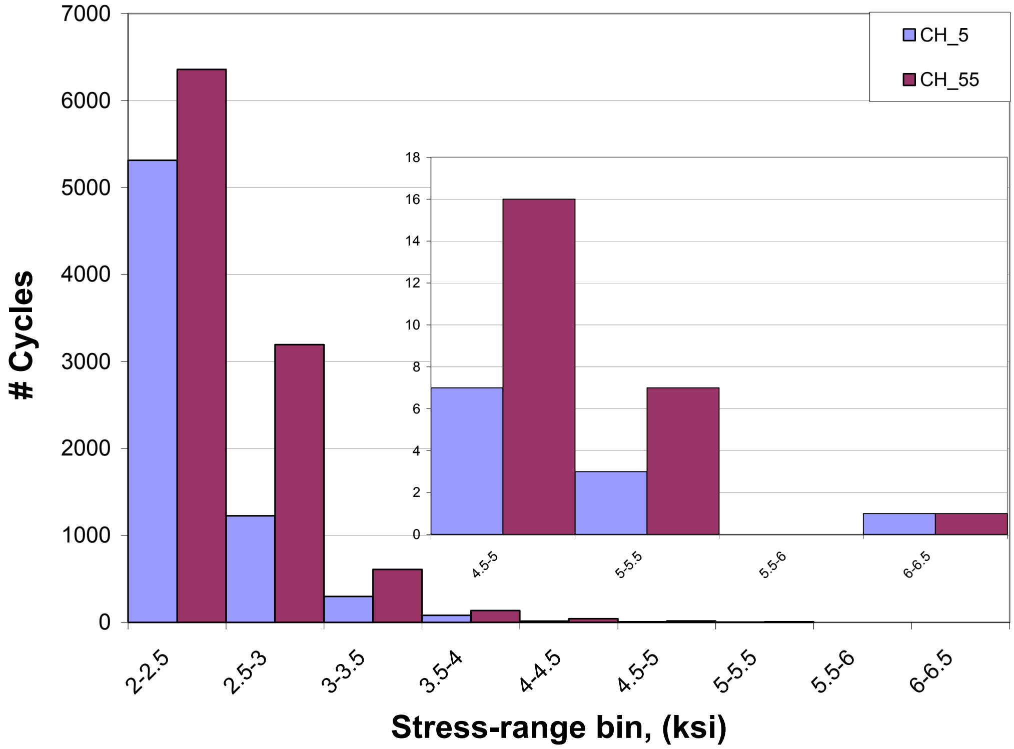


Figure 6.2– Stress-range histogram for strain gages CH_5 and CH_55 installed on the bottom flange of the east girder in Span 34 and Span 35, respectively, at 4 ft north of mid span

Channel	Fatigue Life Calculation Summary								
	S_{rmax} (ksi)	Cycles > CAFL #	Cycles > CAFL %	S_{reff} (ksi)	Cycles / Day	Days Mon.[3]	Remaining Life (Years)[2]	Cat.	Location
CH_4	5.8	0	0	2.5	3	43.55	Infinite	D	East girder top flange, Span 34
CH_5	6.3	0	0	2.5	235	43.55	Infinite	D	East girder bot. flange, Span 34
CH_54	4.8	0	0	2.4	215	43.55	Infinite	D	East girder top flange, Span 35
CH_55	6.3	0	0	2.6	351	43.55	Infinite	D	East girder bot. flange, Span 35
CH_33	3.3	0	0	2.4	1	38.93	Infinite	D	East girder top flange, Span 36
CH_34	4.8	0	0	2.5	127	38.93	Infinite	D	East girder bot. flange, Span 36
CH_59	4.8	0	0	2.5	159	38.93	Infinite	D	East girder top flange, Span 38
CH_60	4.8	0	0	2.4	111	38.93	Infinite	D	East girder bot. flange, Span 38
CH_29	5.8	0	0	3.3	1	49.61	Infinite	D	East girder top flange, Span 45
CH_30	4.8	0	0	2.6	148	49.61	Infinite	D	East girder bot. flange, Span 45

Note
1. The effective stress range and cycles per day calculations ignore cycles less than 1.75 ksi
2. The remaining fatigue life calculations are from 2005 forward
3. Number of days monitored

Table 6.1 - Summary of fatigue life calculations of strain gages CH_4, CH_54, CH_33, CH_59, and CH_29 installed on the top flange of the east girders at 4 ft north of mid span of Span 34, Span 35, Span 36, Span 38, and Span 45, respectively, and strain gages CH_5, CH_55, CH_34, CH_60, and CH_30 installed on the bottom flange of the east girders at 4 ft north of mid span of Span 34, Span 35, Span 36, Span 38, and Span 45, respectively.

6.2.2 Stresses in the Riveted/Bolted Floorbeam Flange

Four strain gages were installed on the top and bottom flange of Floorbeam 1 and floorbeam2 in span 45. On Floorbeam 1, strain gages FB1_Top and FB1_Bot were installed on the top and bottom flange of the floorbeam, respectively, on the reduced section of the floorbeam flange at 1 in from the termination of the cover plate riveted/bolted to the bottom flange (9ft-1 in west of mid span of the floorbeam) and at 4 in from the edge of the flange. Strain gages FB1_Top and FB2_Bottom were installed on the top and bottom flange, respectively, of Floorbeam 2 at mid span of the floorbeam, where gage FB1_Bot was installed at the centerline of the floorbeam on the bottom flange at 4 in from the edge of the flange and gage FB2_Top was installed at the centerline of the floorbeam on the bottom face (because of accessibility) of the top flange at 4 in from the edge of the flange.

The detail is classified as Category D detail per the AASHTO Specifications with a CAFL of 7 ksi. Figure 6.2 presents the stress-range histogram for strain gage FB1_Top and FB1_Bot. installed on the top and bottom flange, respectively, of Floorbeam 1 at 9ft-1 in west of mid span of the floorbeam and FB2_Top installed on the top flange of Floorbeam 2 at mid span of the floorbeam. As shown in the figure, no stress-range cycles higher than the CAFL of the detail were measured. The inset in the figure shows the highest stress-range cycles measured during the long-term monitoring to be 4.75 in strain gages FB1_Top and FB2_Bot. The histogram was produced using a lower-bound stress range truncation level of 1.75 ksi, which is approximately 1/4 of the CAFL of the detail. A summary of the fatigue life calculations is presented in Table 6.2. As shown in the table, infinite fatigue life is estimated for the floorbeam riveted flange detail. Strain gage FB2_Bot. was observed to be unstable during the long-term monitoring and was therefore not used to estimate the remaining fatigue life of the detail.

The relative magnitude of the stresses measured by strain gage FB2_Bot. with respect to the stresses measured by the other strain gages installed on Floorbeam 1 and Floorbeam 2 can be seen in Figure 6.3. The figure shows a typical response of the four strain gages (FB1_top, FB1_Bot., FB2_Top, and FB2_Bot.). It is important to note that the collected time-history response data of the gages showed that, in some events, the gages installed on the top flange of the floorbeams experience tensile stresses while the gages installed on the bottom flange of the floorbeams experienced compressive stresses (Figure 6.3). This could be due to a particular transverse configuration of the vehicles crossing on the bridge over the floorbeams, which could have forced the floorbeams to experience double curvature.

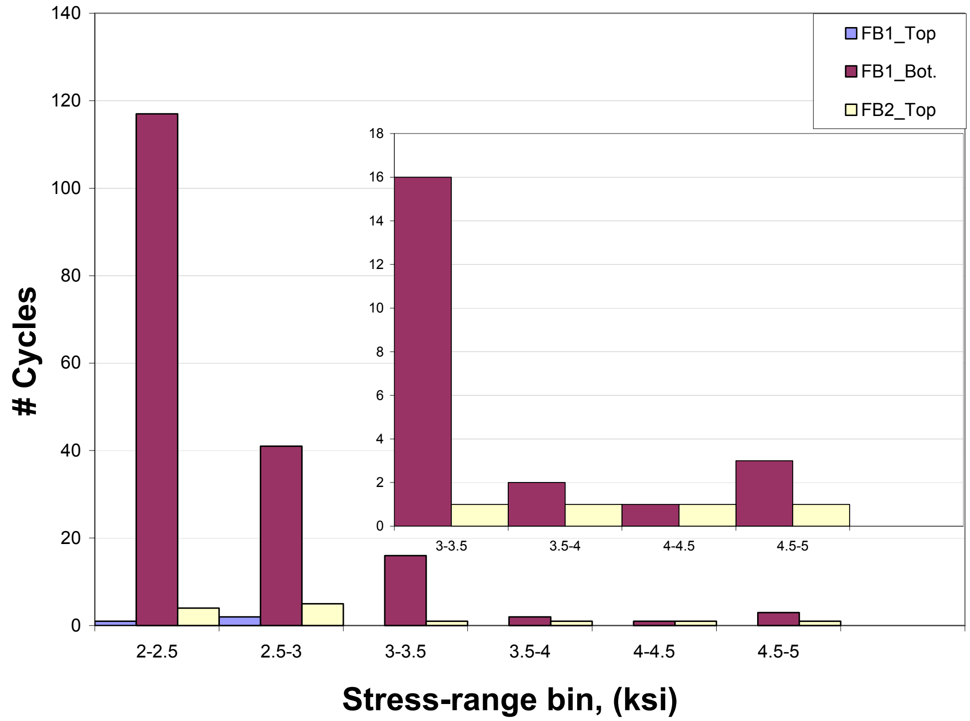


Figure 6.2 – Stress-range histogram for strain gages FB1_Top, FB1_Bot., installed on the top and bottom flange, respectively, of Floorbeam 1 at 9ft-1 in west of mid span of the floorbeam and strain gage FB2_Top installed on the top flange of Floorbeam 2 at mid span of the floorbeam.

Channel	Fatigue Life Calculation Summary								
	S_{rmax} (ksi)	Cycles > CAFL		S_{reff} (ksi)	Cycles / Day	Days Mon. [3]	Remaining Life (Years)[2]	Cat.	Location
		#	%						
FB1_Top	2.75	0	0	2.6	1	14.01	Infinite	D	Top flange Floorbeam 1, Span 45
FB1_Bot.	4.75	0	0	2.6	12	14.01	Infinite	D	Bot. flange Floorbeam 1, Span 45
FB2_Top	4.75	0	0	3.2	1	14.01	Infinite	D	Top flange Floorbeam 2, Span 45
FB2_Bot.	--	--	--	--	--	14.01	--	D	Bot. flange Floorbeam 2, Span 45

Notes
1. The effective stress range and cycles per day calculations ignore cycles less than 1.75 ksi
2. The remaining fatigue life calculations are from 2005 forward
3. Number of days monitored
4. "--" indicates unstable data during long-term monitoring

Table 6.2 - Summary fatigue life calculations of FB1_Top, FB1_Bot., installed on the top and bottom flange, respectively, of Floorbeam 1 at 9ft-1 in west of mid span of the floorbeam and strain gage FB2_Top installed on the top flange of Floorbeam 2 at mid span of the floorbeam

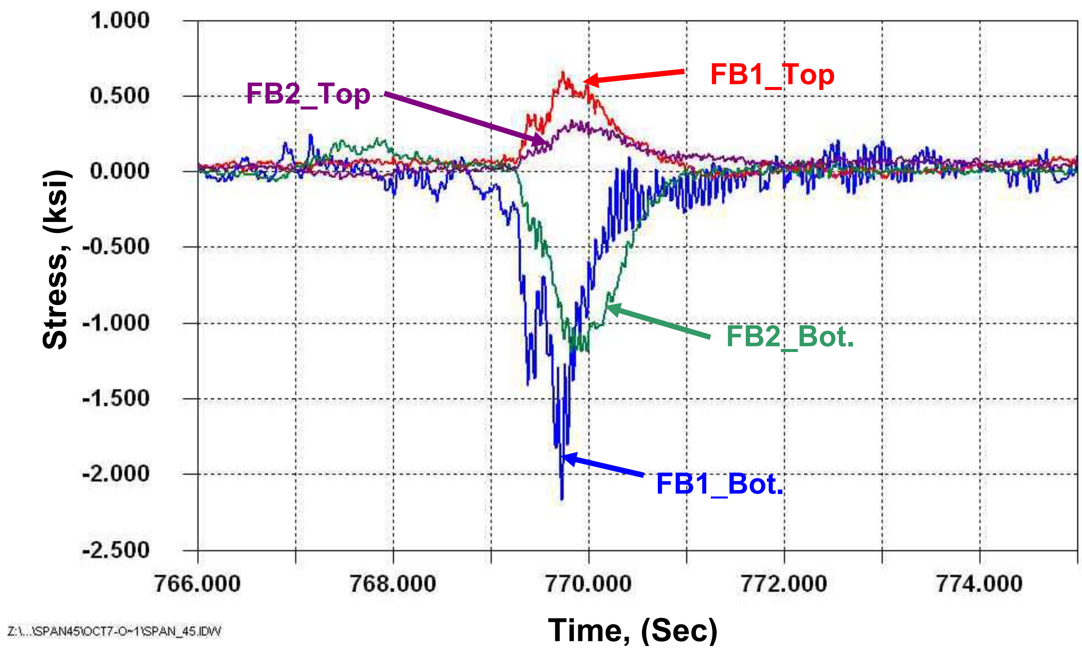


Figure 6.3 – Response of strain gage strain gages FB1_Top, FB1_Bot., installed on the top and bottom flange, respectively, of Floorbeam 1 at 9ft-1 in west of mid span of the floorbeam and strain gages FB2_Top and FB2_Bot. installed on the top flange of Floorbeam 2 at mid span of the floorbeam

6.2.3 Stresses in the WT-Section Bolted to Floorbeam Web

Strain gages were installed on the prototype WT's, connected to the web of various floorbeams to measure the out-of-plane bending stresses in the WT's that could be induced on the floorbeam web by the lateral bracing system. Specifically, strain gage CH_41 was installed on the WT of Floorbeam 2 in Span 35 on the south face of the floorbeam web, strain gage CH_15 was installed on the WT of Floorbeam 8 in Span 36 on the north face of the floorbeam web, and CH_18 was installed on the WT of Floorbeam 2 in Span 45 on the north face of the floorbeam web. The gages were installed at a distance of approximately 21 1/2 in west of the centerline of the east girder and approximately 5 1/2 in below the bottom face of the floorbeam top flange.

The detail where the gages were installed is classified as Category B detail per AASHTO Specifications with a CAFL of 16 ksi. Figure 6.3 presents the stress-range histogram for strain gage CH_41. As shown in the figure, stress-range cycles higher than the CAFL of the detail were not measured. The inset in the figure shows stress-range cycles as high as 9.75 ksi were recorded by strain gage CH_41 during long-term monitoring. The histogram was produced using a lower-bound stress range truncation level of 4.0 ksi, which is approximately 1/4 of the CAFL of the detail. The highest stress-range cycles measured by strain gages CH_18 and CH_15, and CH_41 during the monitoring period are 1.25 ksi, 2.75 ksi, and 9.75 ksi, respectively. A summary of the fatigue life calculations is presented in Table 6.3. As shown in the table, infinite fatigue life is estimated for all instrumented bolted WT's details.

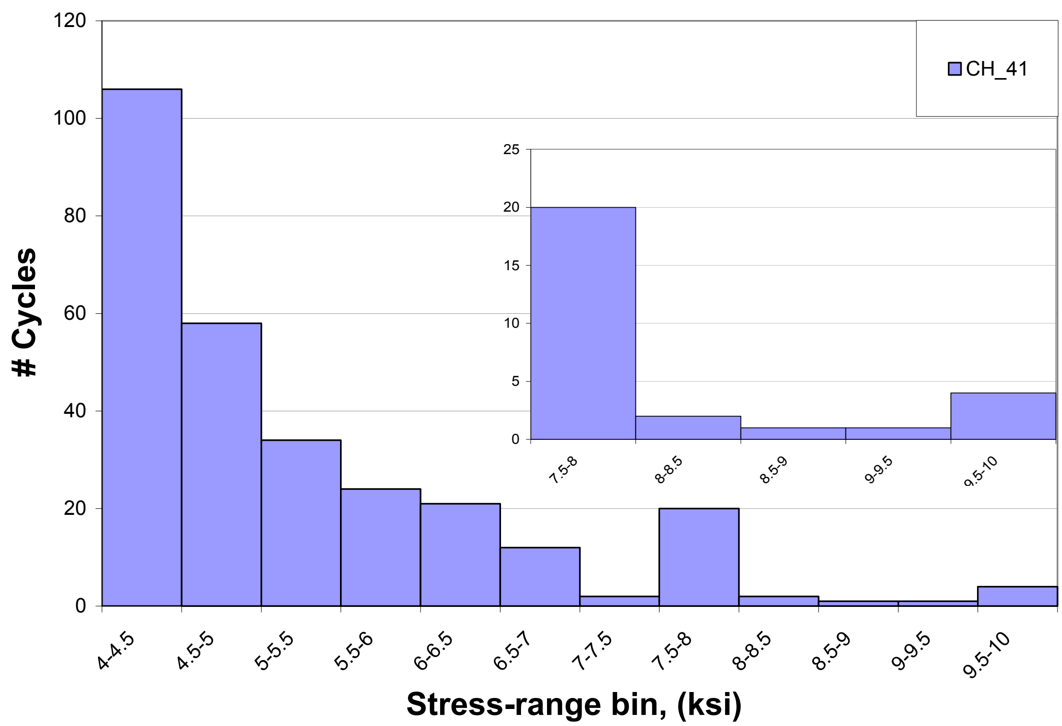


Figure 6.3 – Stress-range histogram for strain gage CH_41 installed on the WT bolted to the web of Floorbeam 2 (on the south face of the floorbeam web) in Span 35

Channel	Fatigue Life Calculation Summary								
	S_{rmax} (ksi)	Cycles > CAFL		S_{reff} (ksi)	Cycles / Day	Days Mon.[3]	Remaining Life (Years)[2]	Cat.	Location
		#	%						
CH_41	9.75	0	0	5.6	10	43.55	Infinite	B	WT of Floorbeam 2, Span 35
CH_18	1.25	0	0	Note 4	0	38.93	Infinite	B	WT of Floorbeam 8, Span 36
CH_15	2.75	0	0	Note 4	0	49.61	Infinite	B	WT of Floorbeam 2, Span 45

Notes
1. The effective stress range and cycles per day calculations ignore cycles less than 4.0 ksi
2. The remaining fatigue life calculations are from 2005 forward
3. Number of days monitored
4. Details with S_{rmax} less than the stress truncation level used for the fatigue calculations are assigned 0 cycles/day and S_{reff} can not be calculated

Table 6.3 - Summary of fatigue life calculations of strain gages CH_41, CH_18, and CH_15 installed on the WT's bolted to the web of Floorbeam 2 in Span 35, to the web of Floorbeam 8 in Span 36, and the web of Floorbeam 2 in Span 45, respectively

6.2.4 Stresses in the Riveted Tie Plate

A total of nine strain gages were installed on riveted tie plates of selected floorbeams, which cross transversely over the east girder and connect the top flange of the main floorbeam on the west side of the girder to the top flange of the cantilevered floorbeam outboard of the girder. In Span 34, strain gage CH_12 was installed on the south edge of the tie plate of Floorbeam 8. In Span 35, strain gages CH_39 and CH_40 were installed on the south and north edge, respectively, of the tie plate of Floorbeam 2. In Span 36 strain gages CH_16 and CH_17 were installed on the south and north edge, respectively, of the tie plate of Floorbeam 8. In Span 38, strain gages CH_45 and CH_46 were installed on the south and north edge, respectively, of the tie plate of Floorbeam 2. Finally on Span 45, strain gages CH_12 and CH_13 were installed on the south and north edge, respectively, of the tie plate of Floorbeam 2. All gages were installed on the tie plates at 4 in west of the centerline of the east girder except for strain gages CH_16 and CH_17 installed in Span 36. Strain gages CH_16 and CH_17 were installed on the tie plate at the centerline of the east girder.

The detail where the gages were installed is classified as Category D detail per AASHTO Specifications with a CAFL of 7 ksi. Figure 6.4 presents the stress-range histogram for strain gages CH_39 and CH_40. The inset in the figure shows that stress-range cycles as high as 7.25 ksi, which is higher than the CAFL of the detail were recorded by strain gage CH_40 during long-term monitoring. The histogram was produced using a lower-bound stress range truncation level of 2.0 ksi, which is approximately 1/4 of the CAFL of the detail. The highest stress-range cycle measured by all strain gages during the monitoring period was 8.75 ksi and was recorded by strain gage CH_12 installed in Span 45. A summary of the fatigue life calculations is presented in Table 6.4. As shown in the table, infinite fatigue life is estimated for all instrumented riveted tie plate details except for the tie plate of Floorbeam 2 in Span 35 and the tie plate of Floorbeam 2 in Span 45. The estimated remaining fatigue life at the north and south edge of the details at these two locations, which was partially calculated using strain gage CH_40 and CH_12, was calculated to be over 100 years.

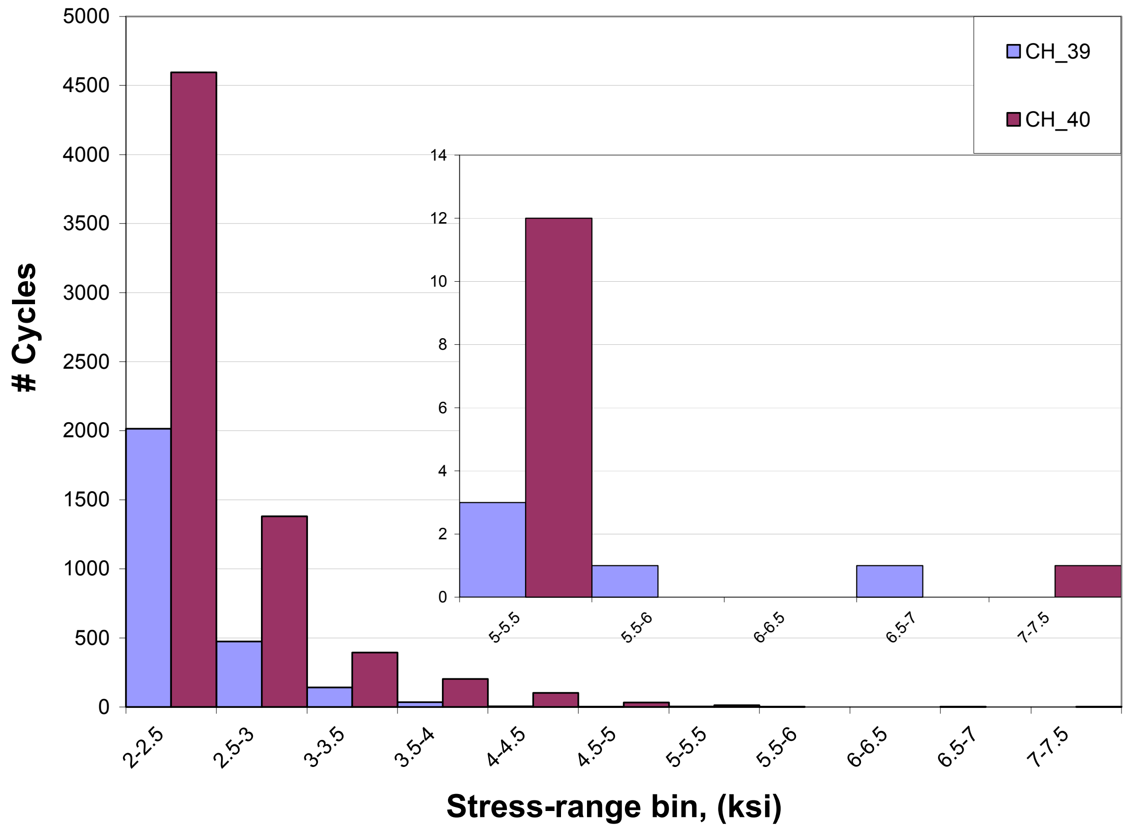


Figure 6.4 – Stress-range histogram for strain gages CH_39 and CH_40 installed on the south and north edge, respectively, of the tie plate of Floorbeam 2, which crosses transversely over the east girder in Span 35

Channel	Fatigue Life Calculation Summary								
	S_{rmax} (ksi)	Cycles > CAFL #	Cycles > CAFL %	S_{reff} (ksi)	Cycles / Day	Days Mon.[3]	Remaining Life (Years)[2]	Cat.	Location
CH_12	5.25	0	0	2.5	16	43.55	Infinite	D	South edge tie plate of Floorbeam 8, Span 34
CH_39	6.75	0	0	2.5	91	43.55	Infinite	D	South edge of tie plate of Floorbeam 2,Span 35
CH_40	7.25	1	0.015	2.6	228	43.55	Over 100	D	North edge of tie plate of Floorbeam 2, Span 35
CH_16	2.75	0	0	2.3	3.7	38.93	Infinite	D	South edge of tie plate of Floorbeam 8, Span 36
CH_17	2.75	0	0	2.3	1	38.93	Infinite	D	North edge of tie plate of Floorbeam 8, Span 36
CH_45	4.75	0	0	2.5	37	38.93	Infinite	D	South edge of tie plate of Floorbeam 2, Span 38
CH_46	4.25	0	0	2.5	35	38.93	Infinite	D	North edge of tie plate of Floorbeam 2, Span 38
CH_12	8.75	3	0.74	2.8	8	49.61	Over 100	D	South edge of tie plate of Floorbeam 2, Span 45
CH_13	3.25	0	0	2.4	5	49.61	Infinite	D	North edge of tie plate of Floorbeam 2, Span 45

Notes
1. The effective stress range and cycles per day calculations ignore cycles less than 1.75 ksi
2. The remaining fatigue life calculations are from 2005 forward
3. Number of days monitored

Table 6.4 - Summary of fatigue life calculations of strain gages CH_12, CH_39, CH_40, CH_16, CH_17, CH_45, CH_46, CH_12, and CH_13 installed at various locations on the riveted tie plate details in all five spans

6.2.5 Stresses in the Web of Prototype Shear Connectors at Cutout Detail

The prototype shear connectors are made of built-up sections and contain fatigue-prone details, which include welded details, bolted details, and cutout details of the shear connector web plate. The cutout detail of the web plate exists in the prototype shear connectors of Span 34 and Span 45. The fatigue performance of this detail was evaluated using the collected long-term data. Strain gages were installed back to back at a ¼ in from the cutout. Strain gages CH_23 and CH_24 were installed back-to-back on the web plate at the south cutout detail of the east shear connector located at the north end of Span 34. The gages were installed on the cutout at a vertical distance of approximately 27 in from the top face of the top flange of the east girder. Similarly, strain gages CH_25 and CH_26 were installed back-to-back on the same plate at a vertical distance of approximately 20 1/2 in from the top face of the top flange of the east girder. In Span 45, Strain gages CH_33 and CH_34 were installed back-to-back at similar location to the strain gages CH_23 and CH_24 installed on Span 34. Strain gages CH_35 and CH_36 were installed on the same cutout detail at location similar to where strain gages CH_25 and CH_26 were installed in Span 34.

The detail where the gages were installed is classified as Category detail A per AASHTO Specifications with a CAFL of 24 ksi. Figure 6.5 presents the stress-range histogram for strain gages CH_23 and CH_25. The inset in the figure shows that stress-range cycles as high as 19.75 ksi. The histogram was produced using a lower-bound stress range truncation level of 6 ksi, which is approximately 1/4 of the CAFL of the detail. A summary of the fatigue life calculations is presented in Table 6.5. As shown in the table, infinite fatigue life is estimated for all instrumented cutout details.

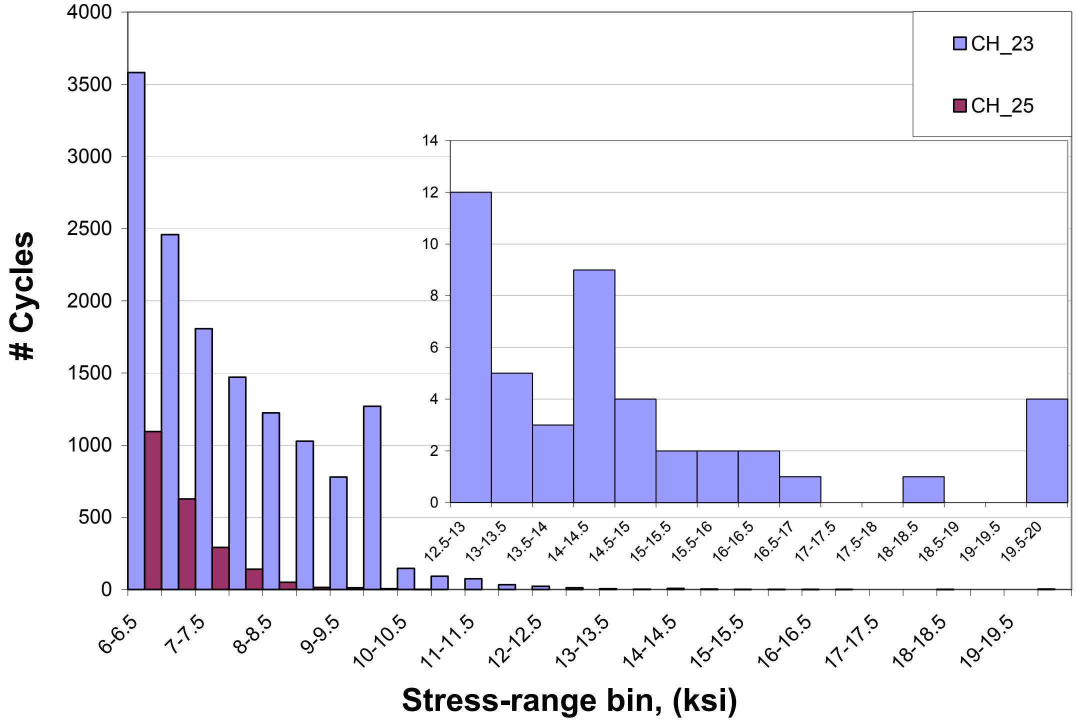


Figure 6.5 – Stress-range histogram for strain gages CH_23 and CH_25 installed on the south cutout detail of the east shear connector located at the north end of Span 34

Channel	Fatigue Life Calculation Summary								
	S_{rmax} (ksi)	Cycles > CAFL #	Cycles > CAFL %	S_{reff} (ksi)	Cycles / Day	Days Mon.[3]	Remaining Life (Years)[2]	Cat.	Location
CH_23	19.75	0	0	7.9	322	43.55	Infinite	A	South cutout, east shear connector, north end of Span 34
CH_24	15.75	0	0	7.7	334	29.51	Infinite	A	South cutout, east shear connector, north end of Span 34
CH_25	10.25	0	0	6.8	52	43.55	Infinite	A	South cutout, east shear connector, north end of Span 34
CH_26	9.25	0	0	6.6	19	43.55	Infinite	A	South cutout, east shear connector, north end of Span 34
CH_33	13.75	0	0	7.2	126	49.61	Infinite	A	South cutout, east shear connector, north end of Span 45
CH_34	13.75	0	0	7.6	178	49.61	Infinite	A	South cutout, east shear connector, north end of Span 45
CH_35	9.75	0	0	8.7	13	49.61	Infinite	A	South cutout, east shear connector, north end of Span 45
CH_36	7.25	0	0	6.6	1	49.61	Infinite	A	South cutout, east shear connector, north end of Span 45

Notes:
1. The effective stress range and cycles per day calculations ignore cycles less than 6 ksi
2. The remaining fatigue life calculations are from 2005 forward
3. Number of days monitored

Table 6.5 - Summary of fatigue life calculations of strain gages CH_23 through CH_26, installed on the south cutout detail of the east shear connector located at the north end of Span 34 and strain gages CH_33 through CH_36 installed on the south cutout detail of the east shear connector located at the south end of Span 45

6.2.6 Stresses in the Web of the Prototype Shear Connectors near Bolted Detail

As previously discussed, triaxial strain rosettes were installed on the web plate of the shear connector at the stiffener angle bolted detail. In Span 36, strain gages CH_5, CH_6, and CH_7 were installed on the shear connector located over the east girder near the north end of the span. The gages were installed on the west face of the shear connector plate, where gage CH_5 was installed vertically on the web plate adjacent to the vertical stiffener angle, gage CH_6 was installed at 45 degree counter-clockwise from gage CH_5, and gage CH_7 was installed longitudinally along the longitudinal angle at 90 degree angle counter-clockwise from gage CH_5. Gages CH_8, CH_9, and CH_10 were installed directly behind gages CH_5, CH_6, and CH_7, respectively, on the east face of the shear connector web plate.

In Span 45, strain gages CH_4, CH_5, and CH_6 were installed on the south shear connector (south end of the span) over the east girder and on the west face of the shear connector plate. Strain gage CH_4 was installed vertically on the web plate adjacent to the vertical stiffener angle, strain gage CH_5 was installed at 45 degree counter-clockwise from strain gage CH_4, and strain gage CH_6 was installed longitudinally along the longitudinal angle at 90 degree angle counter-clockwise from strain gage CH_5. Strain gages CH_7, CH_8, and CH_9 were installed directly behind strain gages CH_4, CH_5, and CH_6, respectively, on the east face of the shear connector web plate.

No laboratory fatigue test data are available for this type of detail under such complicated state of stress. Therefore, no fatigue category can be assigned for the detail per AASHTO Specifications, and hence the estimated fatigue life can not be calculated using the conventional S-N fatigue curves adopted by AASHTO. In Span 36, the highest stress ranges recorded during the monitoring period by the strain gages were 2.25 ksi, 4.75 ksi, 1.75 ksi, 2.25 ksi, 2.75 ksi, and 2.25 in strain gages CH_5, CH_6, CH_7, CH_8, CH_9, and CH_10, respectively. In Span 45, the highest stress ranges recorded during the monitoring period by the strain gages were 9.75 ksi, 9.75 ksi, 1.75 ksi, 8.75 ksi, 4.75 ksi, and 8.75 ksi in strain gages CH_4, CH_5, CH_6, CH_7, CH_8, and CH_9, respectively.

6.2.7 Stresses in the Standing Angle Bolted to Shear Connector

As previously mentioned, strain gages were installed on the vertical stiffener angles bolted to the web plate of the shear connector in Span 34, Span 36, and Span 45. The gages were installed at mid height and mid width of the outstanding leg of the vertical stiffener angle. In Span 34, strain gage CH_27 was installed on the north face of the outstanding leg of the south end stiffener angle bolted to the web of the shear connector at the north end of the span over the east girder. In Span 36, strain gages CH_3 and CH_4 were installed back-to-back on the south and north face, respectively, of the outstanding leg of the north end stiffener angle bolted to the web of the shear connector at the north end of the span over the east girder. In Span 45, strain gages CH_10 and CH_11 were installed back-to-back on the south and north face, respectively, of the outstanding leg of the north end stiffener angle bolted to the web of the shear connector at the south end of the span over the east girder. Strain gage CH_38 was installed in the same span on the north face of the outstanding leg of the south end stiffener angle bolted to the web of the shear connector at the north end of the span over the east girder.

The detail where the gages were installed is classified as Category A detail per AASHTO Specifications with a CAFL of 24 ksi. Figure 6.6 presents the stress-range histogram for strain gages CH_10 and CH_38. The inset in the figure shows that stress-range cycles as high as 6.25 ksi were recorded, which is higher than the CAFL of the detail was recorded by strain gage CH_38 during long-term monitoring. The histogram was produced using a lower-bound stress range truncation level of 6 ksi, which is approximately 1/4 of the CAFL of the detail. A summary of the fatigue life calculations is presented in Table 6.6. As shown in the table, infinite fatigue life is estimated for all instrumented cutout details. Strain gage CH_27 appeared to have been damaged during installation and therefore, no fatigue life calculations were made for the location where strain gage CH_27 was installed.

Channel	Fatigue Life Calculation Summary								
	S_{rmax} (ksi)	Cycles > CAFL		S_{reff} (ksi)	Cycles / Day	Days Mon.[3]	Remaining Life (Years)[2]	Cat.	Location
		#	%						
CH_27	--	--	--	--	--	--	--	A	North stiffener, north end of Span 34
CH_3	4.75	0	0	Note 4	0	38.93	Infinite	A	North stiffener, north end of Span 36
CH_4	2.25	0	0	Note 4	0	38.93	Infinite	A	North stiffener, north end of Span 36
CH_10	2.75	0	0	Note 4	0	49.61	Infinite	A	North stiffener, north end of Span 45
CH_11	2.25	0	0	Note 4	0	49.61	Infinite	A	North stiffener, north end of Span 45
CH_38	7.25	0	0	6.6	0	49.61	Infinite	A	South stiffener, north end of Span 45

Notes:
1. The effective stress range and cycles per day calculations ignore cycles less than 6 ksi
2. The remaining fatigue life calculations are from 2005 forward
3. Number of days monitored
4. Details with S_{rmax} less than the stress truncation level used for the fatigue calculations are assigned 0 cycles/day and S_{reff} can not be calculated
5. "--" indicate no calculations available (bad gage)

Table 6.6 - Summary of fatigue life calculations of strain gages CH_3, CH_4, CH_10, CH_11, and CH_38 installed on the standing angles bolted to the web plate of the shear connectors in Span 34, Span 36, and Span 45

6.2.8 Stresses in the Underside Deck Plate at the Termination of the Welded and Bolted Shear Connectors

As previously mentioned, strain gages were installed on the bottom face of the deck plate in the longitudinal and transverse direction to measure the nominal stress in the deck plate at the termination of welded and bolted details. Strain gages CH_28 and CH_32 were installed transversely, in Span 34 and Span 45, respectively on the bottom face of the deck plate at 2 in off-center from the shear connector web near the south end of the north shear connector installed in the span over the east girder. Longitudinal strain gages were installed in Span 34, Span 45, and Span 36. Specifically, strain gage CH_29, and strain gage CH_37 were installed longitudinally on the bottom face of the deck plate at 1 1/2 in from the south termination of the north shear connector's weld in Span 34 and Span 45, respectively. In Span 36, strain gage CH_2 was installed on the bottom face of the deck plate at the north end termination of the north shear connector located above the east girder. The strain gage was installed longitudinally on the bottom face of the deck plate at 1 1/2 in from the termination of the shear connector bolt connecting the shear connector to the bottom face of the deck plate.

The detail where strain gages CH_28, CH_32, CH_29, and CH_37 are installed is classified as Category C detail per AASHTO Specifications with a CAFL of 10 ksi. Figure 6.6 presents the stress-range histogram for strain gages CH_28 and CH_32 installed transversely on the bottom face of the deck plate in Span 34 and Span 45, respectively. The inset in the figure shows that the highest stress-range cycle recorded is 6.75 ksi in CH_28, which is below the CAFL of the detail. Similarly, Figure 6.7 presents the stress-range histogram for strain gages CH_29 and CH_37 installed longitudinally on the bottom face of the deck plate in Span 34 and Span 45, respectively. The inset in the figure shows that the highest stress-range cycles recorded are 6.75 ksi in CH_29, which is also below the CAFL of the detail. A summary of the fatigue life calculations is presented in Table 6.7. As shown in the table, infinite fatigue life is estimated for all instrumented deck plate details.

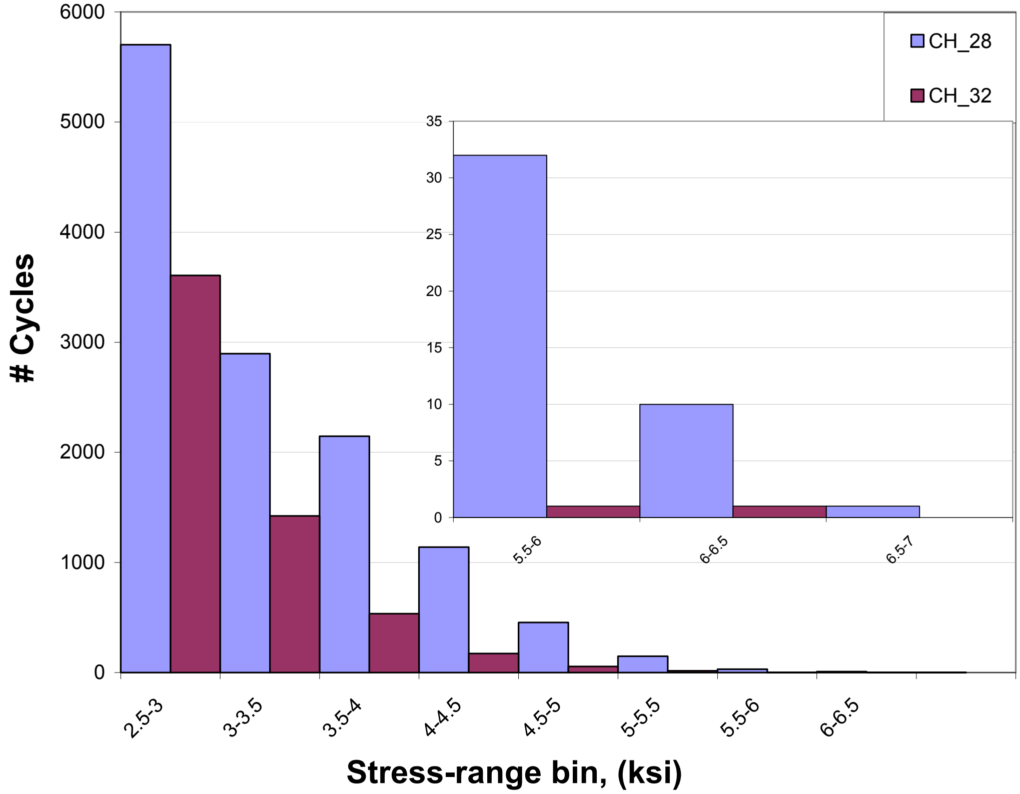


Figure 6.6 – Stress-range histogram for strain gages CH_28 and CH_32 installed transversely, in Span 34 and Span 45, respectively on the bottom face of the deck plate at 2 in off-center from the shear connector web near the south end of the north shear connector installed in the span over the east girder

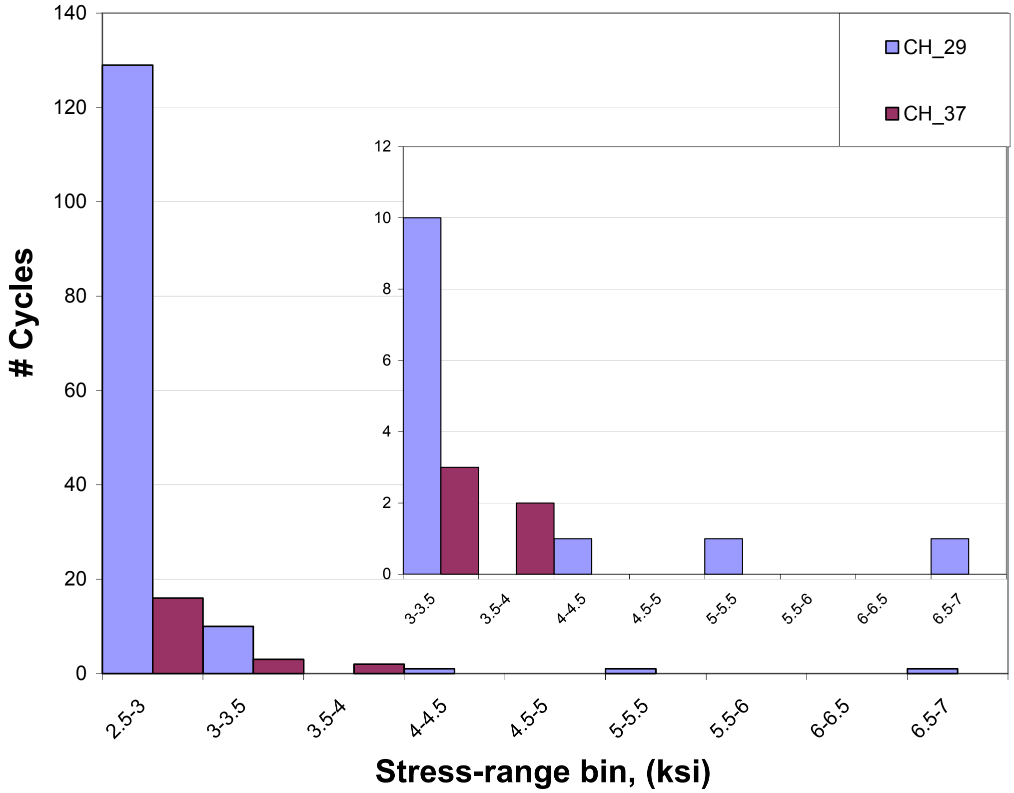


Figure 6.7 – Stress-range histogram for strain gages CH_29 and CH_27 installed longitudinally on the bottom face of the deck plate at 1 1/2" from the south termination of the north shear connector's weld in Span 34 and Span 45, respectively

Channel	Fatigue Life Calculation Summary								
	S_{rmax} (ksi)	Cycles > CAFL #	Cycles > CAFL %	S_{reff} (ksi)	Cycles / Day	Days Mon.[3]	Remaining Life (Years)[2]	Cat.	Location
CH_28	6.75	0	0	3.8	157	43.55	Infinite	C	Deck plate, 2 in off-center of connector web in Span 34
CH_32	6.25	0	0	1.9	286	49.61	Infinite	C	Deck plate, 2 in off-center of connector web in Span 45
CH_29	6.75	0	0	4.1	1	43.55	Infinite	C	Deck plate, 1 1/2" from term. of connector, Span 34
CH_37	3.75	0	0	0.8	8	49.61	Infinite	C	Deck plate, 1 1/2" from term. of long. weld , Span 45
CH_2	3.75	0	0	Note 4	0	38.93	Infinite	B	Deck plate, 1 1/2" from term. of connector bolt, Span 36

Notes
1. The effective stress range and cycles per day calculations ignore cycles less than 2.5 ksi
2. The remaining fatigue life calculations are from 2005 forward
3. Number of days monitored
4. Details with S_{rmax} less than the stress truncation level used for the fatigue calculations are assigned 0 cycles/day and S_{reff} can not be calculated
5. "--" indicate no calculations available (bad gage)

Table 6.7 - Summary of fatigue life calculations of strain gages CH_28 and CH_32 installed transversely on the deck plate at 2 in off-center of the shear connector web near the south end of the north shear connector in Span 34 and Span 45, respectively, and strain gages CH_29 and CH_37 installed longitudinally on the deck plate at 1 1/2" from the south termination of the north shear connector's weld in Span 34 and Span 45, respectively, and CH_2 installed on the deck plate near the end bolts connecting the deck plate to the shear connector in Span 36

6.2.9 Stresses in the Web of Existing Sub-floorbeam near Blocked Flange at Sub-floorbeam-to-Stringer Connection

As discussed previously, biaxial strain gages were installed on the existing sub-floorbeams at the web/flange cutout at the sub-floorbeam-to-stringer connection. In Span 34, biaxial strain gages were installed back-to-back on the web of existing sub-Floorbeam 8 at 1 in below the web/flange cutout (between Rib 5 and Stringer 3), where strain gages CH_13 and CH_14 were installed horizontally and vertically, respectively, on the south face of the web of the sub-floorbeam and strain gages CH_15 and CH_16 were installed on the north face of the web directly behind gages CH_13 and CH_14.

In Span 35, biaxial strain gages were installed back-to-back on the web of existing Sub-floorbeam 2 between Rib 5 and Stringer 3, where strain gages CH_44 and CH_45 were installed horizontally and vertically, respectively, on the south face of the web of the sub-floorbeam. Strain gages CH_46 and CH_47 were installed on the north face of the web directly behind gages CH_44 and CH_45. The gages were installed at 2 3/4 in below the web/flange cutout instead of 1 in as the case in Span 34 because of the existence of an old crack, which had initiated at the web/flange cutout and propagated downwards in the web of the sub-floorbeam.

In Span 38 the gages were installed on the web of existing Sub-floorbeam 2 between Rib 5 and Stringer 3. The biaxial gages were installed back-to-back on the web at 1 in directly below the web/flange cutout. Strain gages CH_48 and CH_49 were installed horizontally and vertically, respectively, on the south face of the web of the sub-floorbeam. Strain gages CH_50 and CH_51 were installed on the north face of the web directly behind gages CH_48 and CH_49.

No laboratory fatigue test data are available for this type of detail under such complicated state of stress. Therefore, no fatigue category can be assigned for the detail per AASHTO Specifications, and hence the estimated fatigue life can not be calculated using the conventional S-N fatigue curves adopted by AASHTO. In Span 34, the highest stress ranges recorded during the monitoring period by the strain gages was 9.75 ksi, 9.25 ksi, and 9.75 ksi in strain gages CH_13, CH_15, and CH_16, respectively, (strain gage CH_14 malfunctioned during the long monitoring). In Span 35, the highest stress ranges recorded during the monitoring period by the strain gages was 5.75 ksi, 11.75 ksi, 7.75 ksi, and 9.75 ksi in strain gages CH_44, CH_45, CH_46, and CH_47. In Span 38, the highest stress ranges recorded during the monitoring period by the strain gages was 10.75 ksi, 6.75 ksi, 10.25 ksi, and 6.75 ksi in strain gages CH_48, CH_49, CH_50, and CH_51.

6.2.10 Stresses in the Top and Bottom Flange of New Sub-floorbeam

As stated earlier, strain gages were installed on the top flange of the new prototype sub-floorbeams near the new sub-floorbeam-to-stringer connection. The top flange of the new sub-floorbeams consists of the web of a built up T-section. The flange of the T-section is bolted to the web of the stringer to provide the connection between the new sub-floorbeam and the stringer. The gages were installed on the top flange near the weld used for attaching the web and the flange of the T-section. Specifically, in Span 36, strain gage CH_20 was installed on the top flange of the new intermediate sub-Floorbeam 8 (i.e., on the web of the new T-section) west of the web of Stringer 3 and near the south end of the flange edge at 1 in from the toe of the weld used for attaching the web and the flange of the T-section and at 1 in from the edge of the reduced section of the flange. Strain gage CH_21 was also installed similar to strain gage CH_20 near the north end of the flange at 1 in from the toe of the weld used for attaching the web and the flange of the T-section and at 1 in from the edge of the reduced section of the flange (directly across from strain gage CH_20). On the east face of the stringer web, the strain gages were installed in a similar fashion to the previously installed gages on the west face of the stringer web such that CH_22 was installed near the south end of the flange, and strain gage CH_23 was installed near the north end of the flange. Strain gages were also installed on the bottom flange of the new sub-floorbeam in Span 36. In particular, two strain gages, CH_24 and CH_25, were installed on the bottom cover plate bolted to the bottom flange of the new sub-Floorbeam 8. In Span 45, strain gages were installed on the top flange of the new Sub-floorbeam 2 similar to those in Span 36. Specifically, strain gages CH_21, CH_22, CH_19, and CH_20 in Span 45 were installed similar to strain gages CH_20, CH_21, CH_22, and CH_23, respectively.

The top flange welded detail can be classified as category C detail per AASHTO Specifications, while the bottom flange bolted cover plate detail can be classified as Category B detail. Figure 6.7 presents the stress-range histogram for strain gages CH_20 and CH_21 installed on the top flange of new Sub-floorbeam 2 in Span 36. As the figure shows, low stress-range cycles were measured by both gages during long-term monitoring. A summary of the fatigue life calculations for all the above mentioned gages is presented in Table 6.8. As shown in the table, infinite fatigue life is estimated for all instrumented top flange welded new sub-floorbeam and bottom flange bolted new sub-floorbeam.

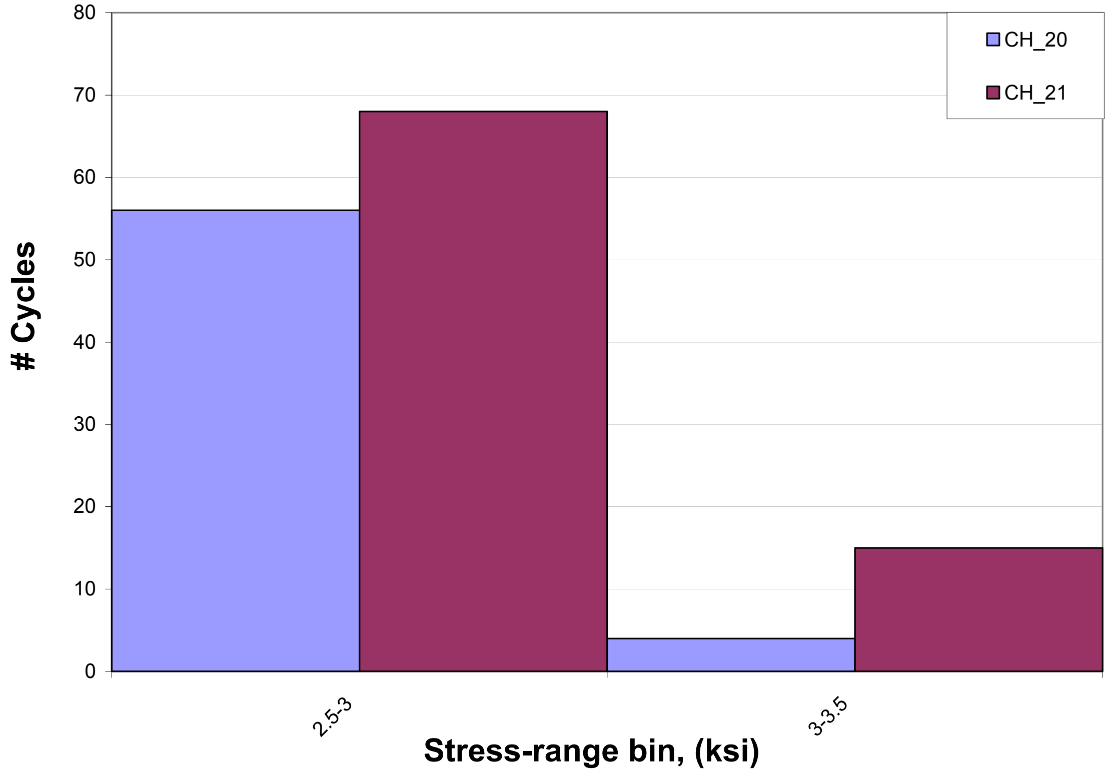


Figure 6.8 – Stress-range histogram for strain gages CH_20 and CH_21 installed in Span 36 on the top flange of new sub-Floorbeam 8 and on the west and east, respectively, of the web of Stringer 3 and near the south end of the flange edge at 1 in from the toe of the weld used for attaching the web and the flange of the build-up T-section and at 1 in from the edge of the reduced section of the flange

Channel	Fatigue Life Calculation Summary								
	S_{rmax} (ksi)	Cycles > CAFL #	Cycles > CAFL %	S_{reff} (ksi)	Cycles / Day	Days Mon.[3]	Remaining Life (Years)[2]	Cat.	Location
CH_20	3.25	0	0	3.25	1	38.93	Infinite	C	Top flange of new Sub-floorbeam 2, Span 36
CH_21	3.25	0	0	3.25	1	38.93	Infinite	C	Top flange of new Sub-floorbeam 2, Span 36
CH_22	3.25	0	0	3.25	1	38.93	Infinite	C	Top flange of new Sub-floorbeam 2, Span 36
CH_23	--	--	--	--	--	--	--	--	Top flange of new Sub-floorbeam 2, Span 36
CH_21	2.25	0	0	Note 4	0	49.61	Infinite	C	Top flange of new Sub-floorbeam 2, Span 45
CH_22	3.25	0	0	3.25	1	49.61	Infinite	C	Top flange of new Sub-floorbeam 2, Span 45
CH_19	2.75	0	0	Note 4	0	49.61	Infinite	C	Top flange of new Sub-floorbeam 2, Span 45
CH_20	4.75	0	0	3.4	3	49.61	Infinite	C	Top flange of new Sub-floorbeam 2, Span 45
CH_24	1.75	0	0	Note 4	0	38.93	Infinite	B	Bottom flange of new Sub-floorbeam 2, Span 36
CH_25	1.75	0	0	Note 4	0	38.93	Infinite	B	Bottom flange of new Sub-floorbeam 2, Span 36

Notes
1. effective stress range and cycles per day calculations ignore cycles less than 2.5 ksi
2. The remaining fatigue life calculations are from 2005 forward
3. Number of days monitored
4. Details with S_{rmax} less than the stress truncation level used for the fatigue calculations are assigned 0 cycles/day and S_{reff} can not be calculated
5. “--“ indicate no calculations available (bad gage)

Table 6.8 - Summary of fatigue life calculations of strain gages CH_20, CH_21, CH_22, and CH_23 installed on the top flange of the new Sub-floorbeam 2 in Span 36, and strain gages CH_21, CH_22, CH_19, and CH_20 installed on the top flange of the new Sub-floorbeam 2 in Span 45, and strain gages CH_24 and CH_25 installed on the bottom flange of new Sub-floorbeam 2 in Span 36

6.2.11 Stresses in the Orthotropic Rib Web Plate

Strain gages were installed on the orthotropic rib web plate near the connection of the rib bearing plates to the sub-floorbeam upper flange to measure the out-of-plane bending stresses in the web plate, if any. The gages were installed in Span 35, Span 36, Span 38, and Span 45. In Span 35, strain gages were installed on the east and west web plate of Rib 6 at Sub-floorbeam 2-to-rib connection. Specifically, strain gages CH_50 and CH_51 were installed on the west web plate of Rib 6 (south west and north west of the plate, respectively) at 2 in vertically from the bottom flange of the rib and approximately 4 1/2 in apart longitudinally (off of the centerline of the sub-floorbeam flange). On the east web plate of the same rib, strain gages CH_52 and CH_53 were installed on the south east and north east of the plate, respectively at 2 in vertically from the bottom flange of the rib and approximately 4 1/2 in apart longitudinally (off of the centerline of the sub-floorbeam flange), where strain gage CH_52 was installed directly across from strain gage CH_50, and strain gage CH_53 was installed directly across from strain gage CH_51.

In Span 36, four strain gages were installed on the east and west web plate of Rib 6 at the connection to sub-Floorbeam 8. Specifically, strain gages CH_28 and CH_30, CH_29, and CH_31 were installed at locations similar to strain gages CH_50 and CH_51, CH_52 and CH_53 in Span 35. In Span 38, four strain gages were installed on the east and west web plate of Rib 6 at the connection to Sub-floorbeam 2. Specifically, strain gages CH_55, CH_56, CH_57 and CH_58 were installed at locations similar to strain gages CH_50 and CH_51, CH_52 and CH_53 in Span 35. In Span 45, four strain gages were installed on the east and west web plate of Rib 6 at the connection to Sub-floorbeam 2. Specifically, strain gages CH_25 and CH_27, CH_26, and CH_28 were installed at locations similar to strain gages CH_50 and CH_51, CH_52 and CH_53 in Span 35.

No laboratory fatigue test data are available for this type of detail. Therefore, no fatigue category can be assigned for the detail per AASHTO Specifications, and hence the estimated fatigue life can not be calculated using the conventional S-N fatigue curves adopted by AASHTO. In Span 35, the highest stress ranges recorded during the monitoring period by the strain gages was 3.25 ksi, 2.75 ksi, and 6.25 ksi in strain gages CH_50, CH_52, and CH_53, respectively, (strain gage CH_51 malfunctioned during long monitoring).. In Span 36, the highest stress ranges recorded during the monitoring period by the strain gages was 5.25 ksi, 4.25 ksi, 2.25 ksi, and 2.75 ksi in strain gages CH_28, CH_30, CH_29, and CH_31, respectively. In Span 38, the highest stress ranges recorded during the monitoring period by the strain gages was 3.75 ksi, 3.75 ksi, and 5.25 ksi in strain gages CH_55, CH_56, and CH_58, respectively, (strain gage CH_57 malfunctioned during long monitoring). In Span 45, the highest stress ranges recorded during the monitoring period by the strain gages was 5.25 ksi, 5.75 ksi, 4.25 ksi, and 6.25 ksi in strain gages CH_25, CH_27, CH_26, and CH_28, respectively.

7.0 Summary and Conclusion

The following section provides a summary of the project and the results of the controlled load testing and long-term monitoring conducted on five approach spans of the Throgs Neck Bridge in New York City.

Instrumentation Plan

1. Instrumentation was installed at various locations on Span 34, Span 35, Span 36, Span 38, and Span 45 to investigate the global response of the spans and the effectiveness of the prototype retrofits installed at specific locations on the Spans. The prototype retrofits included the following:

Span 34

- Welded/bolted shear connectors between the main girders and the orthotropic deck plate at each end of the span

Span 35

- Different repair types for the web of end floorbeams and various intermediate floorbeams at the floorbeam/girder intersection

Span 36

- Bolted shear connectors between the main girders and the orthotropic deck plate at each end of the span
- Different repair types for web of end floorbeams and various intermediate floorbeams at the floorbeam/girder intersection
- New Sub-floorbeam 8 and new end Sub-floorbeam 9
- Keeper blocks on both sides of the orthotropic rib plates

Span 45

- Bolted shear connectors between the main girders and the orthotropic deck plate at each end of the span
- Different repair types for web of end floorbeams and various intermediate floorbeams at the floorbeam/girder intersection
- New Sub-floorbeam 8 and new end Sub-floorbeam 9
- Keeper blocks on both sides of the orthotropic rib plates

2. Instrumentation was also installed at fatigue prone details to estimate the remaining life of existing and new fatigue details.

3. The existence of cracks on the web of the existing sub-floorbeams prevented the installation of strain gages at the blocked flange detail. Instead, the gages were installed on the web below the crack or, in some cases, below the hole drilled to arrest the crack.

Controlled Load Testing

1. In general, the maximum response in the instrumented girders was observed when the test truck was directly located over the instrumented detail.

2. Higher response in some of the instrumented details such as the steel deck plate at the termination of the shear connector was observed when the test truck was located in the middle lane.

3. Localized out-of-plane bending stresses in the cutout details of the shear connectors were observed during some of the controlled load tests.

4. The presence of the shear connectors introduced a composite action between the main girder and the steel deck.

5. Floorbeam retrofit appears to be effective in reducing the out-of-plane bending stresses exerted on the floorbeam web. In general, the data shows that the floorbeam prototype retrofit in Span 36 and Span 45 is more effective than Span 35.

6. Prototype retrofits installed in Span 34 and Span 35 were very effective in reducing the out-of-plane displacement in the sub-floorbeams.

7. Since the location of the strain gages installed in Span 35 is slightly different than the location of the gages installed in Span 34, it is difficult to make direct comparison between the effectiveness of the prototype retrofits installed in Span 34 and Span 35 in reducing the out-of-plane stresses on the sub-floorbeam web. It is however clear that the response of the gages in either of the spans is significantly lower than the gages installed in Span 38 (no retrofits).

Long-Term Monitoring

1. Examples of excessive vibration of the girder during the random monitoring.

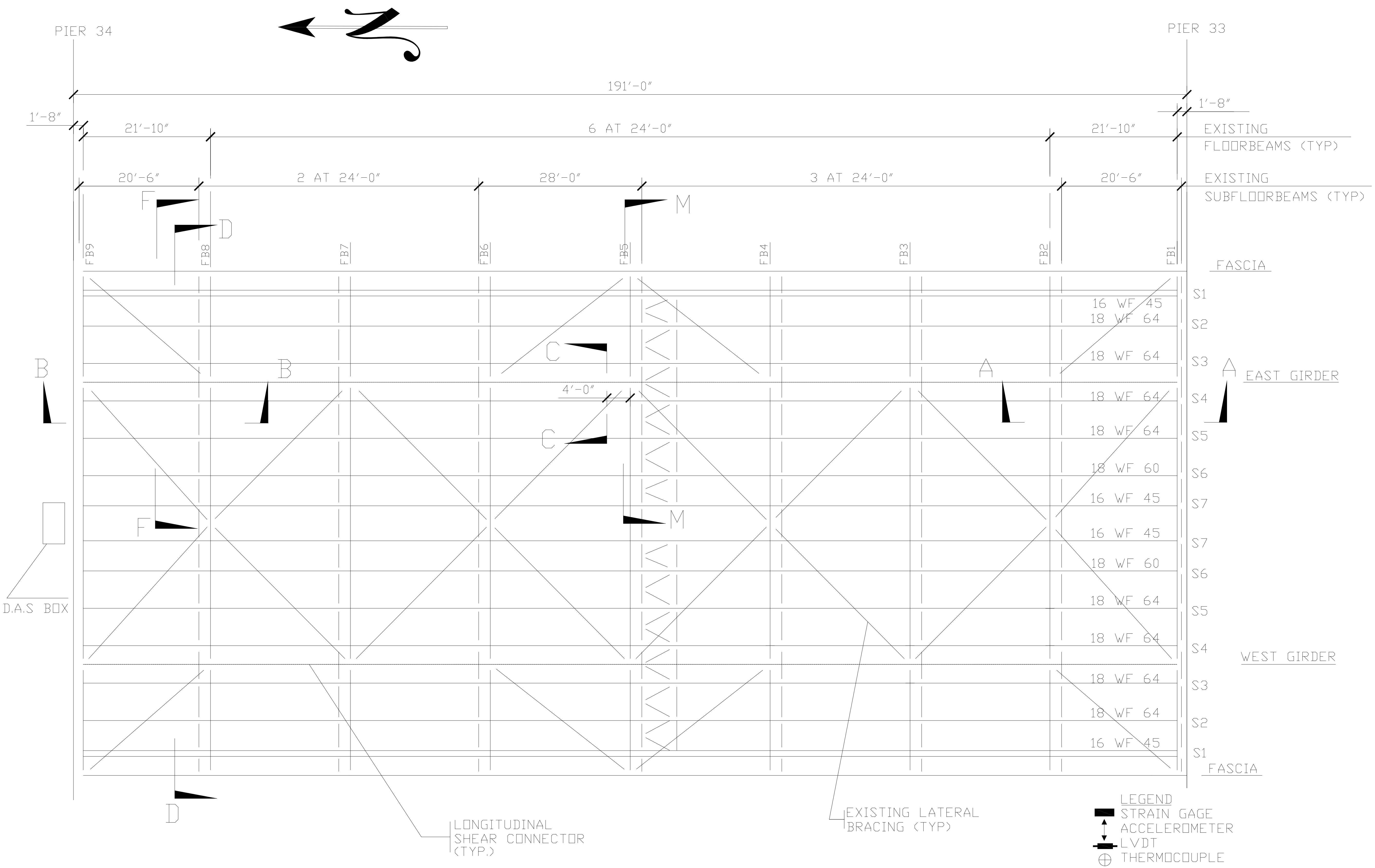
2. In some events, the gages installed on the top flange of the floorbeams experience tensile stresses while the gages installed on the bottom flange of the floorbeams experienced compressive stresses. This could be due to a particular transverse configuration of the vehicles crossing on the bridge over the floorbeams, which could have forced the floorbeams to experience double curvature.

3. Rain-flow analysis conducted using the collected long-term data indicated high (over 100 years) or infinite remaining fatigue life for all of the instrumented fatigue prone details.

4. Laboratory fatigue data are not available for some of the instrumented details and therefore, no fatigue evaluation was conducted for these details.

Appendix A

Instrumentation Plans



CHANNEL PLAN LAYOUT (SPAN 34)

SCALE: 1/16"=1'-0"

ATLSS
ADVANCED TECHNOLOGY FOR LARGE STRUCTURAL SYSTEMS
117 ATLSS Drive
Lehigh University
Bethlehem, PA 18015
610-758-3535 FAX 610-758-6842

PROJECT:

THROGS NECK OVER THE EAST RIVER NEW YORK, NY

SHEET NOTES:

SPAN 34

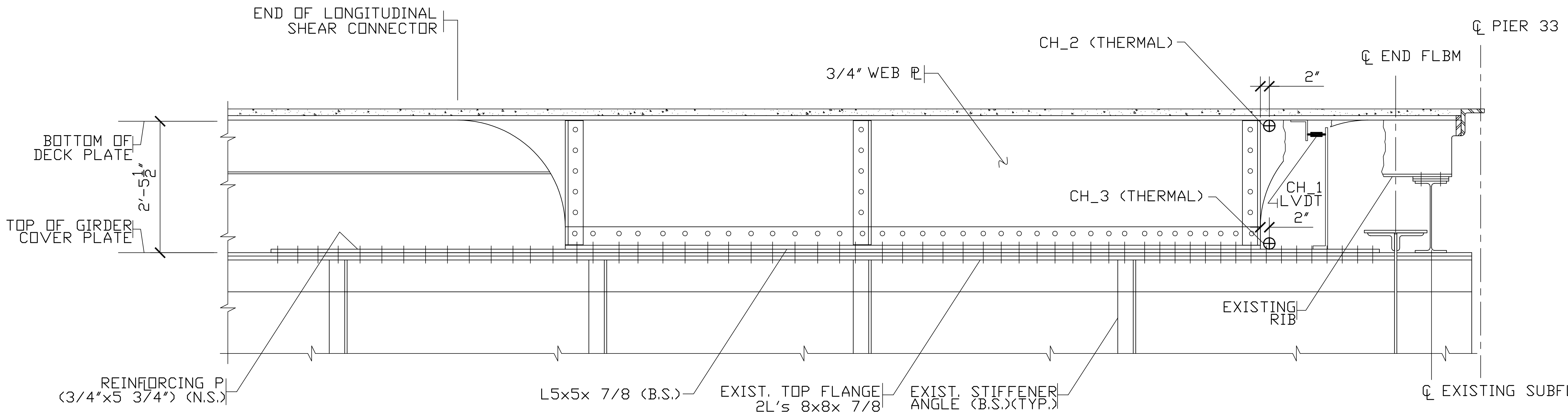
NO.	DESCRIPTION	DATE	BY
1	INITIAL SUBMITTAL	??/??	HNM

DESIGNED BY:	RJC & HNM
DRAWN BY:	HNM
CHECKED BY:	RJC
SCALE:	1/16" = 1'-0"
DATE:	5/12/05
PROJECT NO.:	526701
SHEET TITLE:	

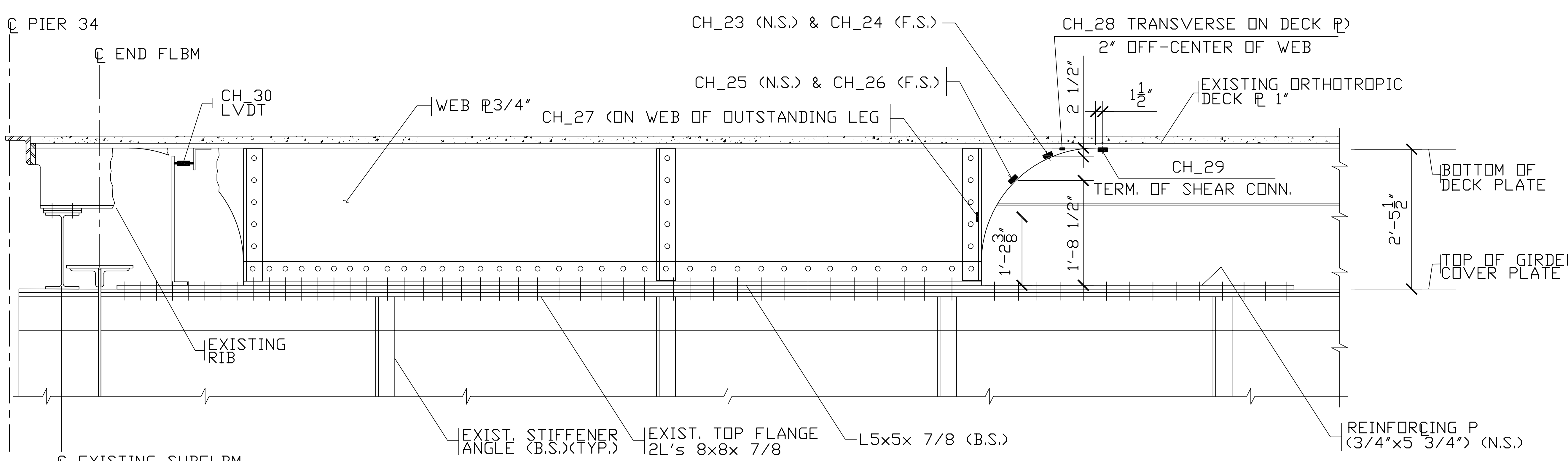
SHEET TITLE

SHEET NO.:

1 OF 7



SECTION A-A
LOOKING EAST
SCALE: 1/2"=1'-0"



SECTION B-B
LOOKING EAST
SCALE: 1/2"=1'-0"

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610-758-3535 FAX 610-758-6842

PROJECT:

THROGS NECK OVER THE EAST RIVER NEW YORK, NY

SHEET NOTES:

SPAN 34

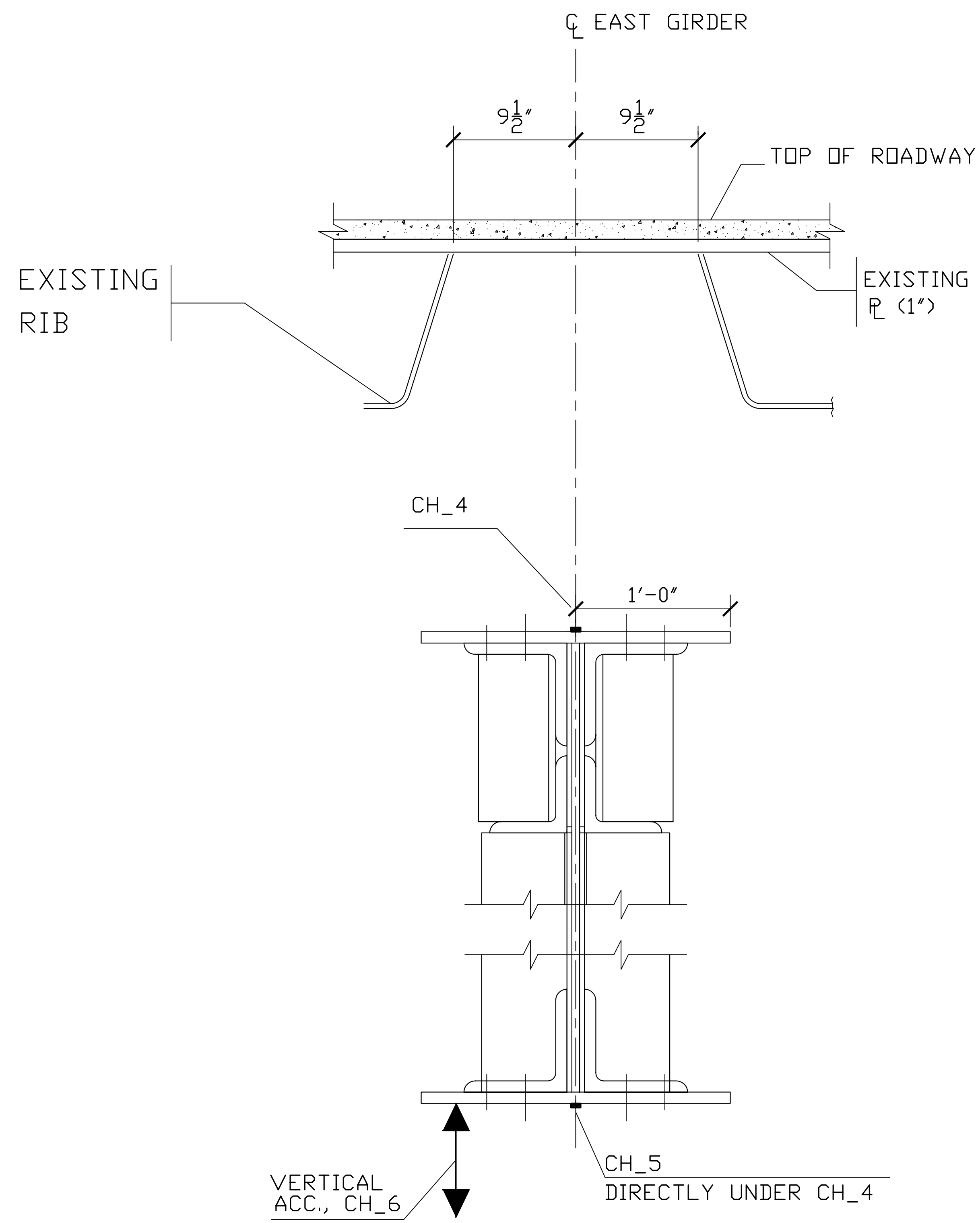
NO.	DESCRIPTION	DATE	BY
1	INITIAL SUBMITTAL	?/?/??	

DESIGNED BY:	RJC & HNM
DRAWN BY:	HNM
CHECKED BY:	RJC
SCALE:	1/2" = 1'-0"
DATE:	5/12/05
PROJECT NO.:	526701
SHEET TITLE:	

SHEET TITLE

SHEET NO.:

2 OF 7



SECTION C-C
LOOKING NORTH
SCALE: 1"=1'-0"

117 ATLSS Drive
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PROJECT:

THROGS NECK OVER THE EAST RIVER NEW YORK, NY

SHEET NOTES:

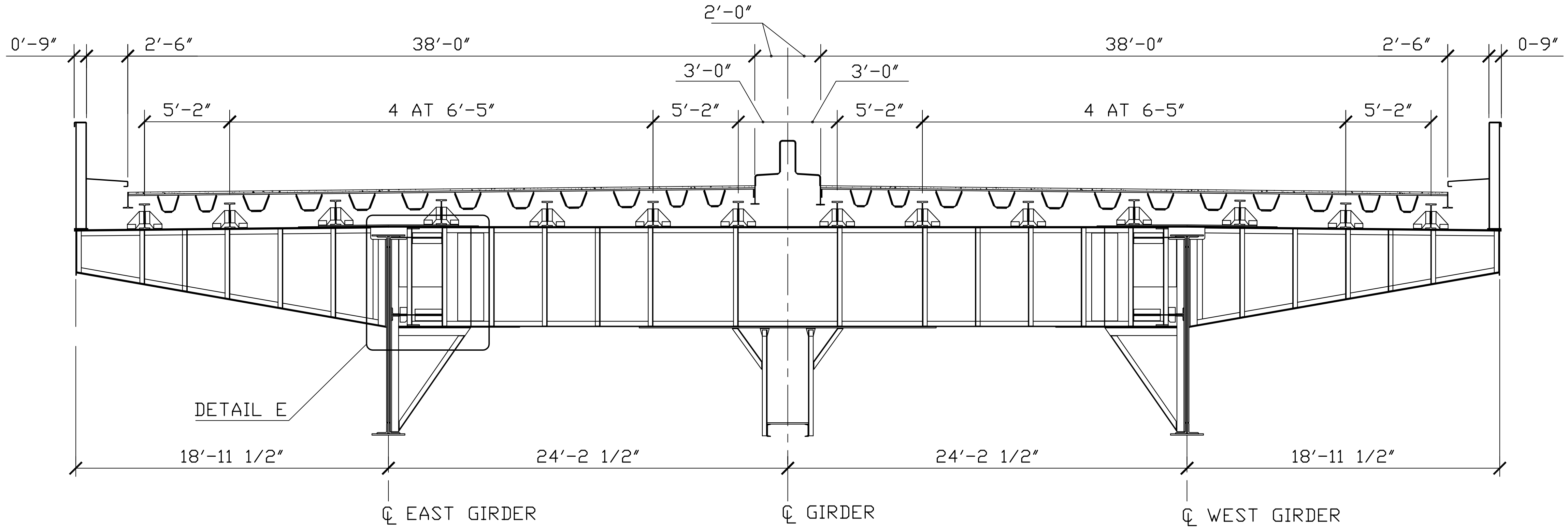
SPAN 34

NO.	DESCRIPTION	DATE	BY
1	INITIAL SUBMITTAL	??/??/??	

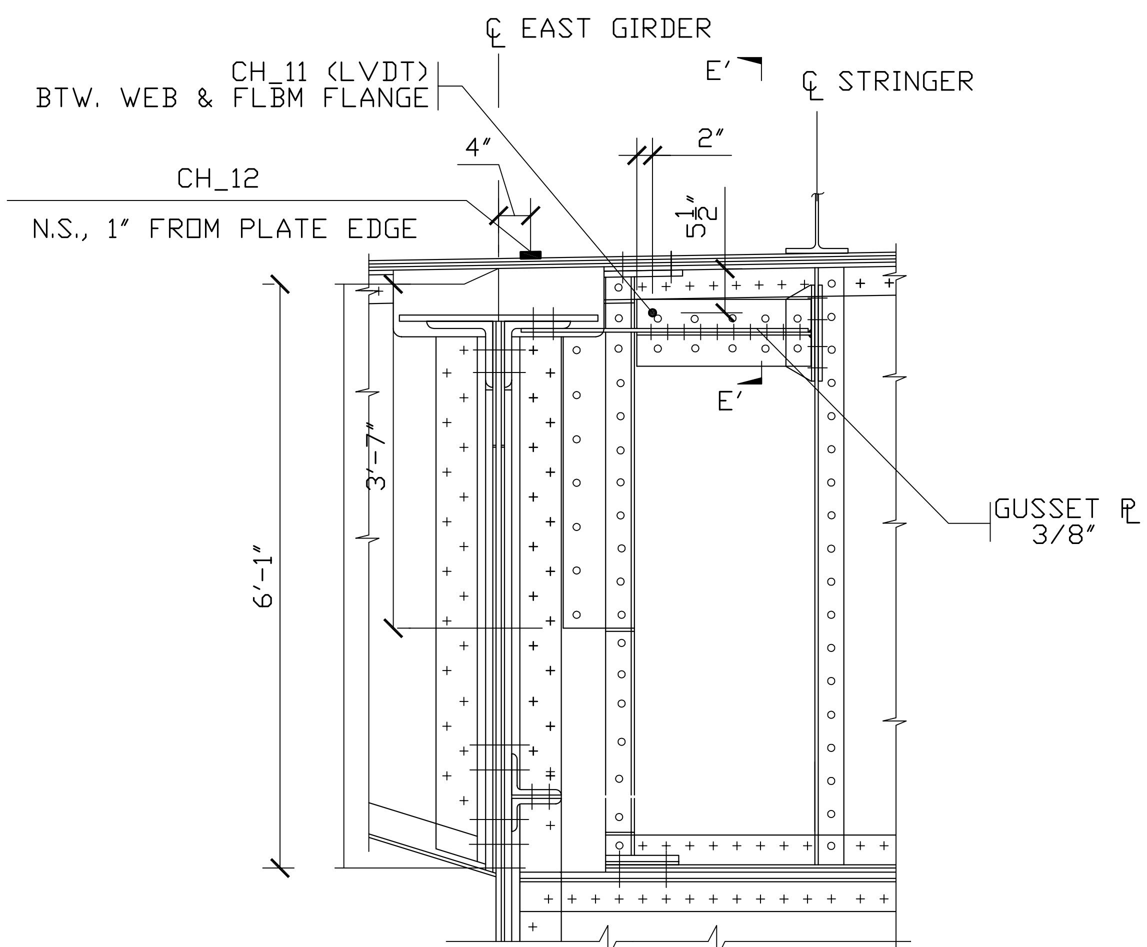
DESIGNED BY:	RJC & HNM
DRAWN BY:	HNM
CHECKED BY:	RJC
SCALE:	1" = 1'-0"
DATE:	5/12/05
PROJECT NO.:	526701
SHEET TITLE:	

SHEET TITLE

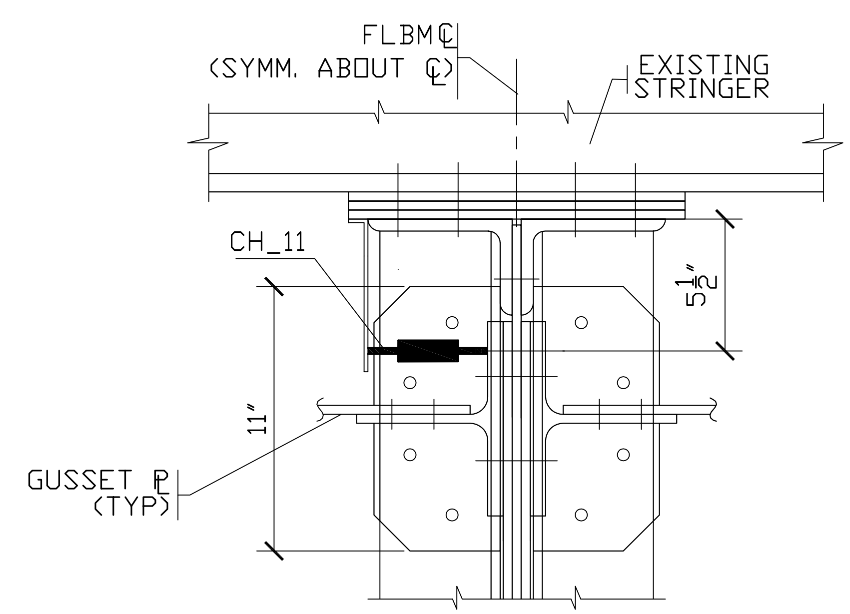
SHEET NO.:



SECTION D-D: FLOORBEAM NO. 8
VIEW LOOKING SOUTH
SCALE: 1/8"=1'-0"



DETAIL E (NO WEB RETROFIT)
LOOKING SOUTH
SCALE: 1/2"=1'-0"



SECTION: E'-E'
LOOKING EAST
SCALE: 1 1/2"=1'-0"

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PROJECT:

THROGS NECK OVER THE EAST RIVER NEW YORK, NY

SHEET NOTES:

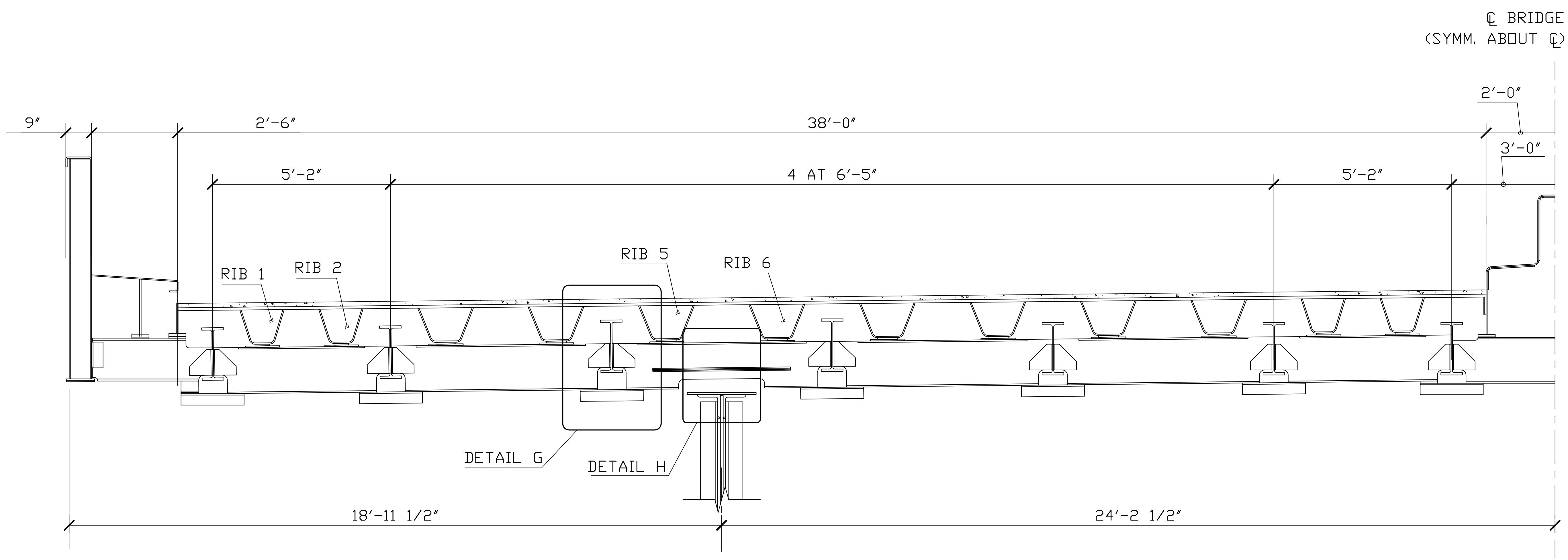
SPAN 34

NO.	DESCRIPTION	DATE	BY
1	INITIAL SUBMITTAL	?/?/??	

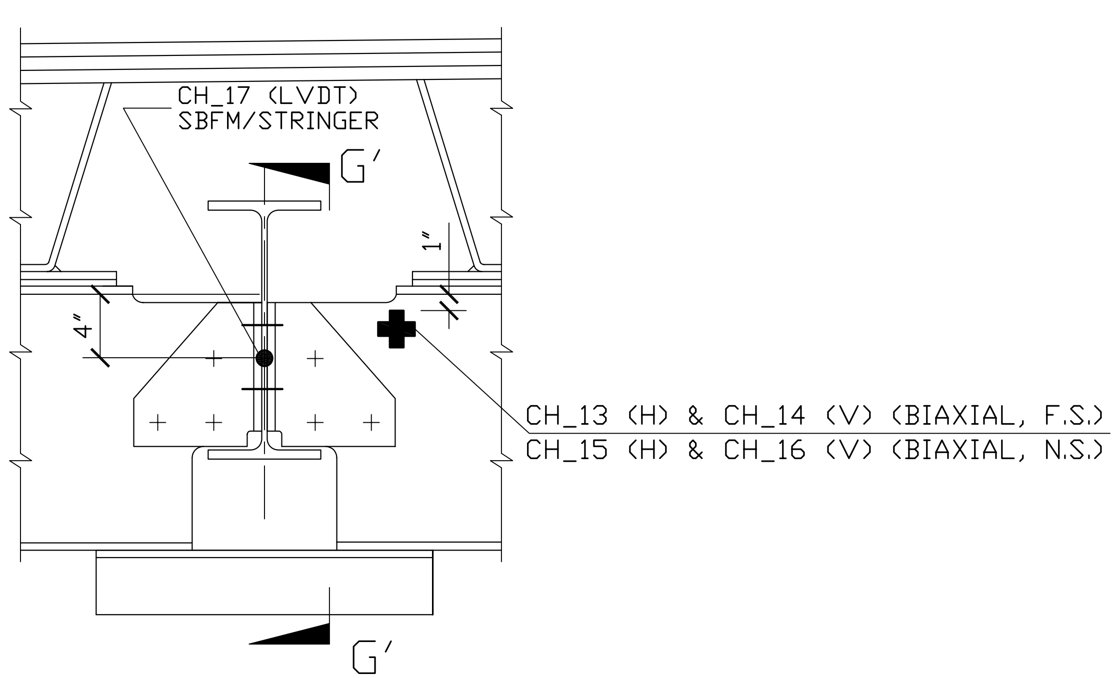
DESIGNED BY:	RJC & HNM
DRAWN BY:	HNM
CHECKED BY:	RJC
SCALE:	1/8" = 1'-0"
DATE:	5/12/05
PROJECT NO.:	526701
SHEET TITLE:	

SHEET TITLE

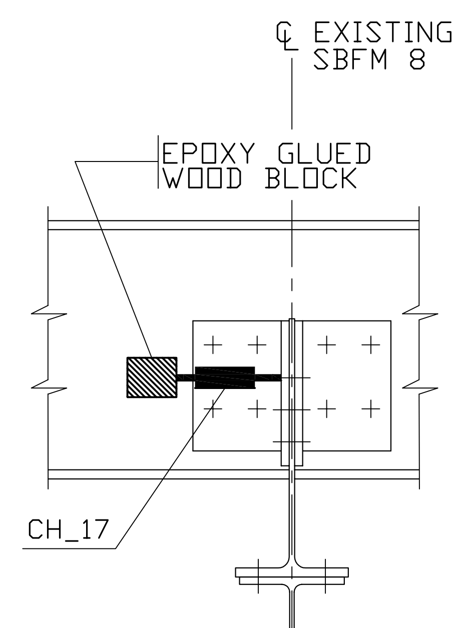
SHEET NO.:



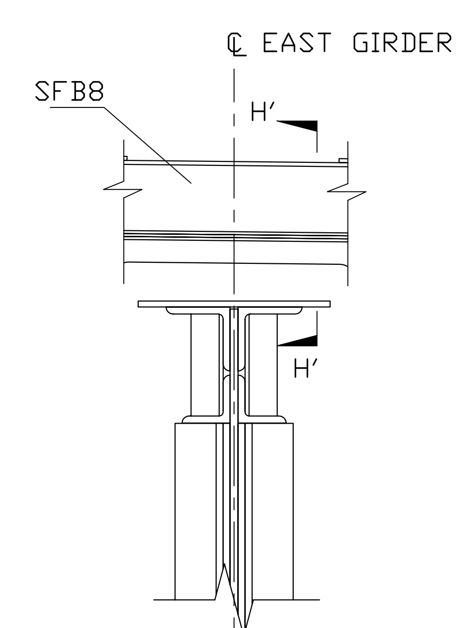
SECTION F-F: AT INTERMEDIATE SUBFLOORBEAM 8
LOOKNG SOUTH
SCALE: 5/16″=1′-0″



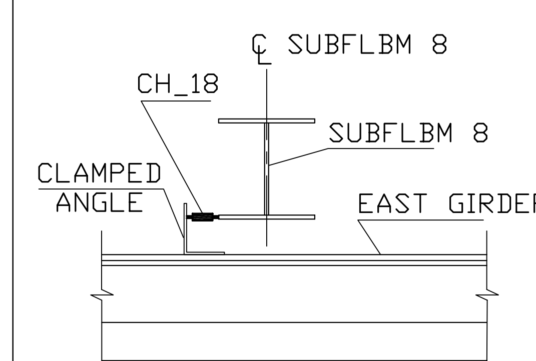
DETAIL G
LOOKING SOUTH
SCALE: 1″=1′-0″



SECTION: G′-G′
LOOKING EAST
SCALE: 1″=1′-0″



DETAIL H
LOOKING SOUTH
SCALE: 1/2″=1′-0″



SECTION H′-H′
LOOKING EAST
SCALE: 1/2″=1′-0″

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PROJECT:

THROGS NECK OVER THE EAST RIVER NEW YORK, NY

SHEET NOTES:

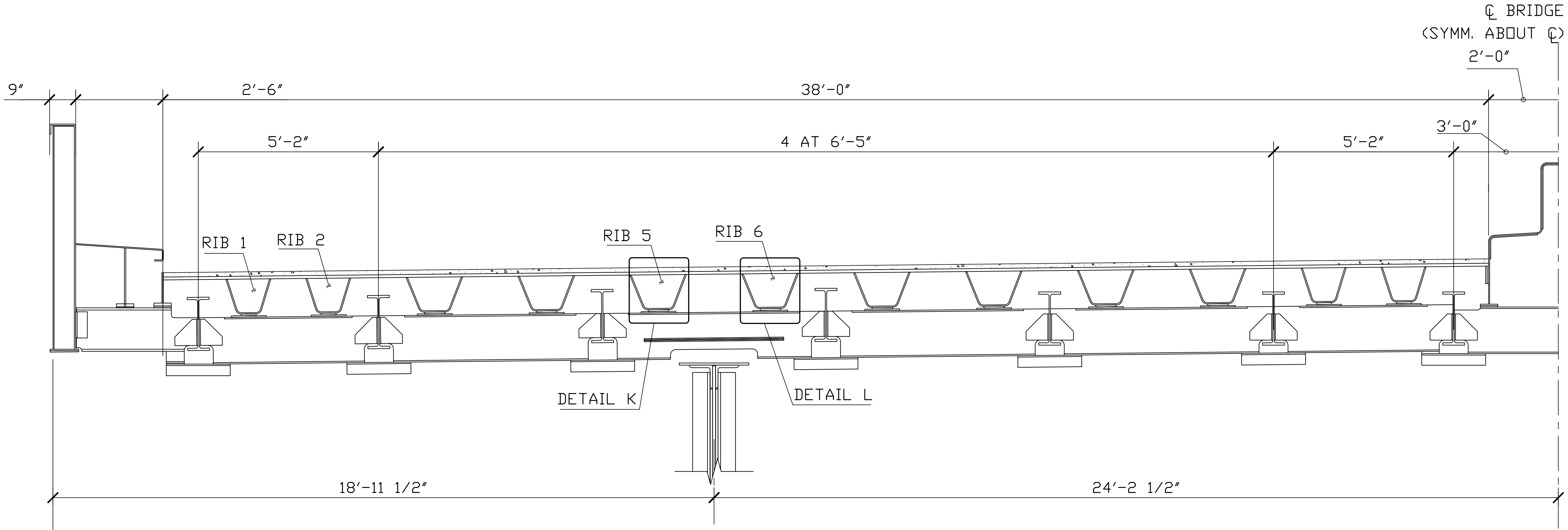
SPAN 34

NO.	DESCRIPTION	DATE	BY
1	INITIAL SUBMITTAL	??/??/??	

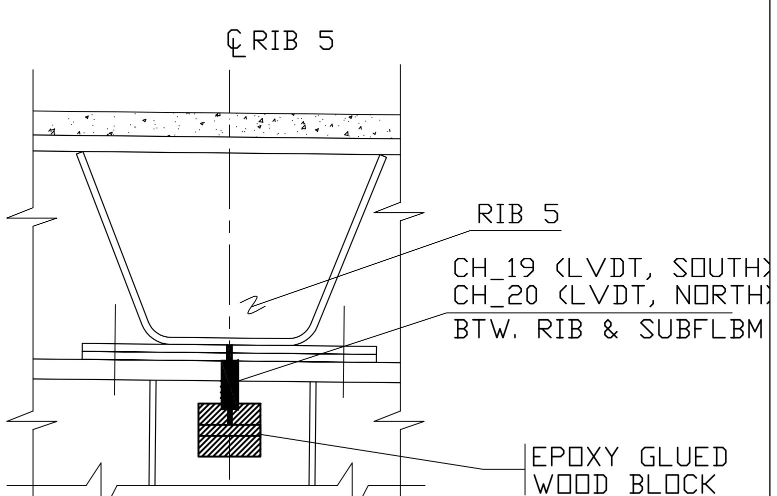
DESIGNED BY:	RJC & HNM
DRAWN BY:	HNM
CHECKED BY:	RJC
SCALE:	VARIES
DATE:	5/12/05
PROJECT NO.:	526701
SHEET TITLE:	

SHEET TITLE

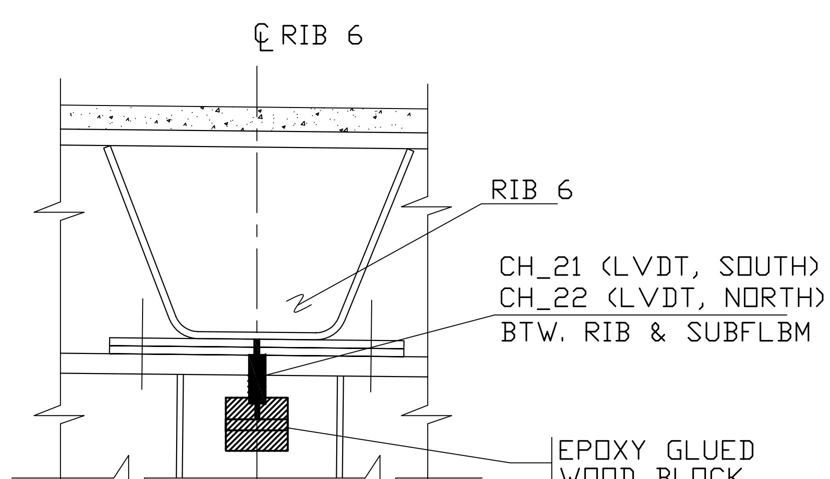
SHEET NO.:



SECTION F-F: AT INTERMEDIATE SUBFLOORBEAM 8
LOOKNG SOUTH
SCALE: 5/16"=1'-0"



DETAIL K
LOOKING SOUTH
SCALE: 1"=1'-0"



DETAIL L
LOOKING SOUTH
SCALE: 1"=1'-0"

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PROJECT:

THROGS NECK OVER THE EAST RIVER NEW YORK, NY

SHEET NOTES:

SPAN 34

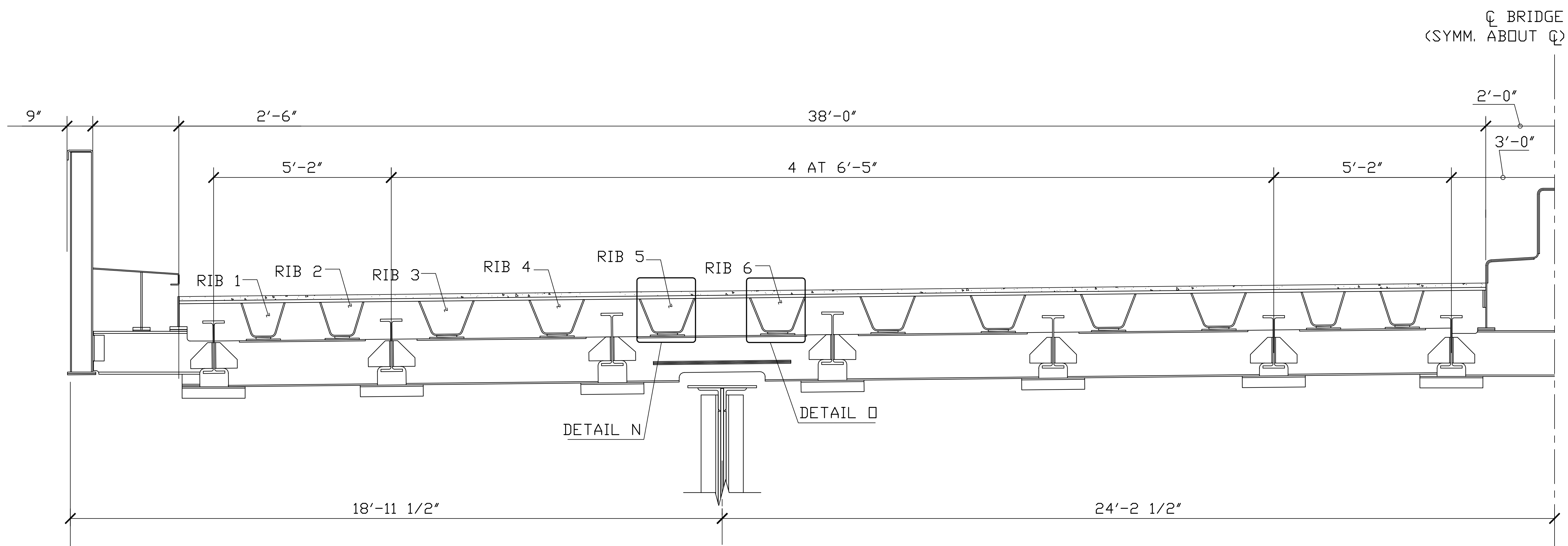
NO.	DESCRIPTION	DATE	BY
1	INITIAL SUBMITTAL	?/?/??	

DESIGNED BY:	RJC & HNM
DRAWN BY:	HNM
CHECKED BY:	RJC
SCALE:	VARIES
DATE:	5/12/05
PROJECT NO.:	526701
SHEET TITLE:	

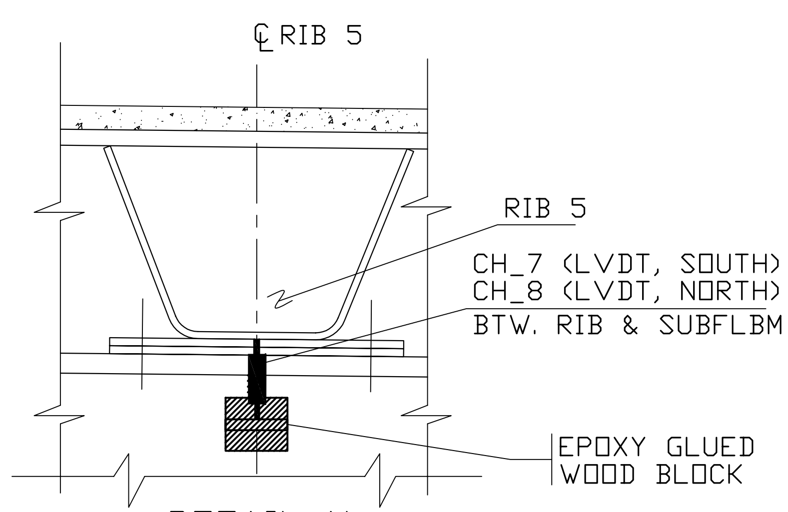
SHEET TITLE

SHEET NO.:

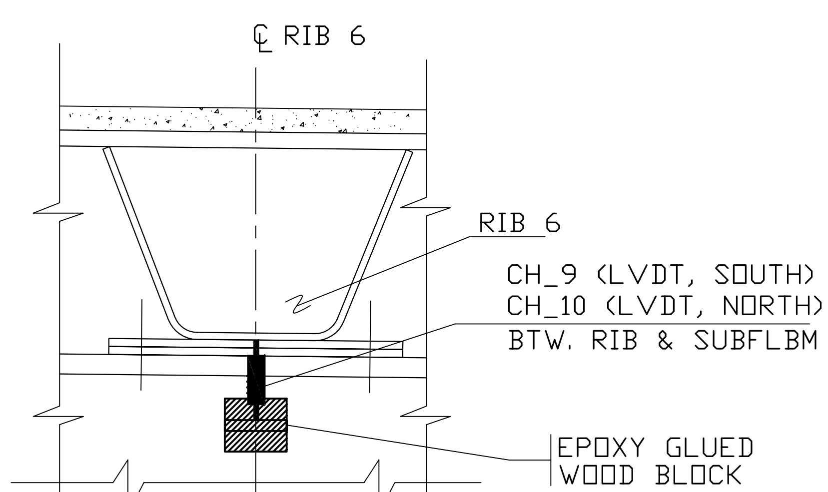
6 OF 7



SECTION M-M: AT INTERMEDIATE SUBFLOORBEAM 5
LOOKNG SOUTH
SCALE: 5/16"=1'-0"



DETAIL N
LOOKING SOUTH
SCALE: 1"=1'-0"



DETAIL O
LOOKING SOUTH
SCALE: 1"=1'-0"

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PROJECT:
THROGS NECK OVER THE EAST RIVER NEW YORK, NY

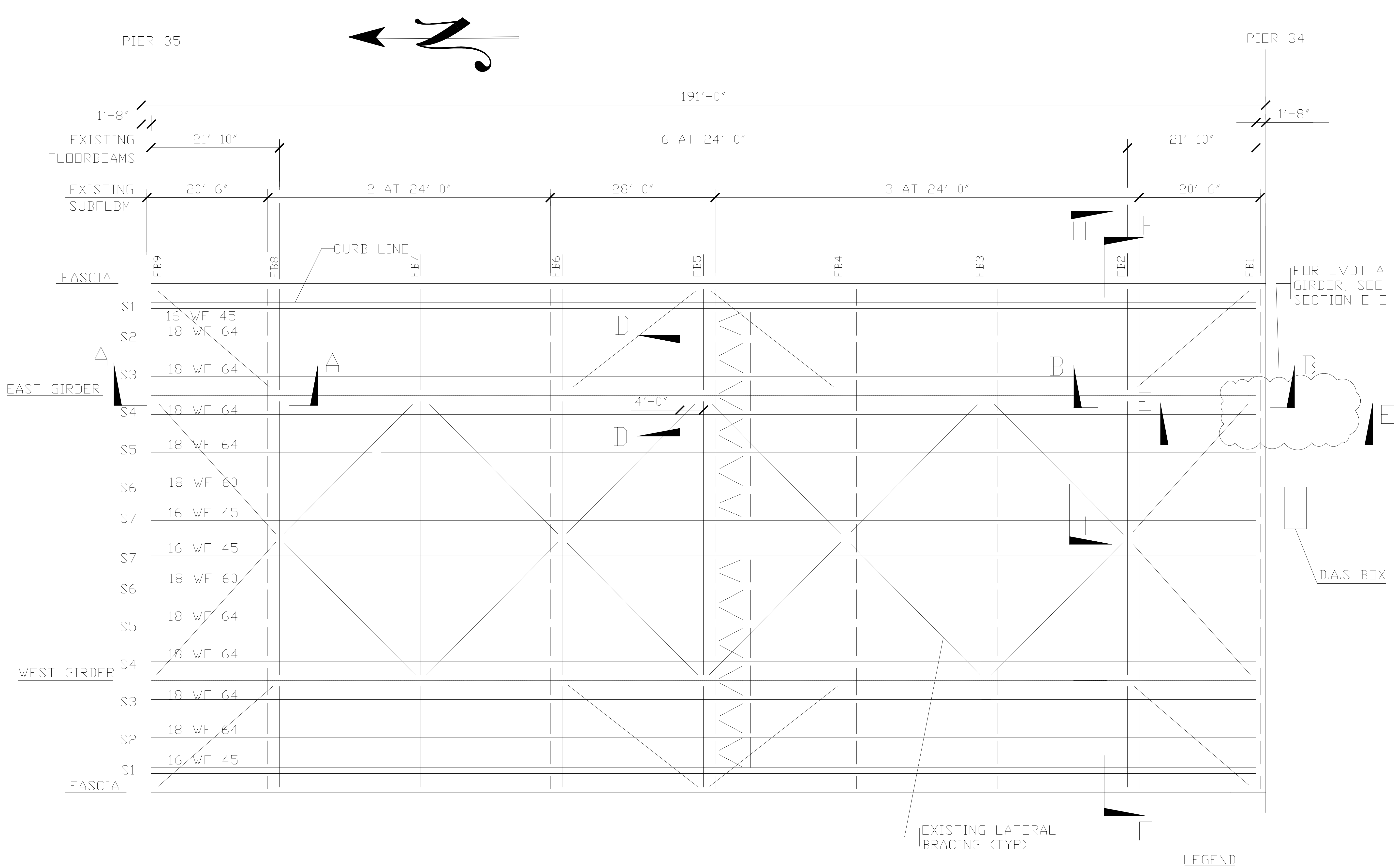
SHEET NOTES:
SPAN 34

NO.	DESCRIPTION	DATE	BY
1	INITIAL SUBMITTAL	?/?/??	

DESIGNED BY:	RJC & HNM
DRAWN BY:	HNM
CHECKED BY:	RJC
SCALE:	VARIES
DATE:	5/12/05
PROJECT NO.:	526701
SHEET TITLE:	

SHEET TITLE

SHEET NO.:



CHANNEL PLAN LAYOUT (SPAN 35)

SCALE: 1/16"=1'-0"

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PROJECT:

THROGS NECK OVER THE EAST RIVER NEW YORK, NY

SHEET NOTES:

SPAN 35

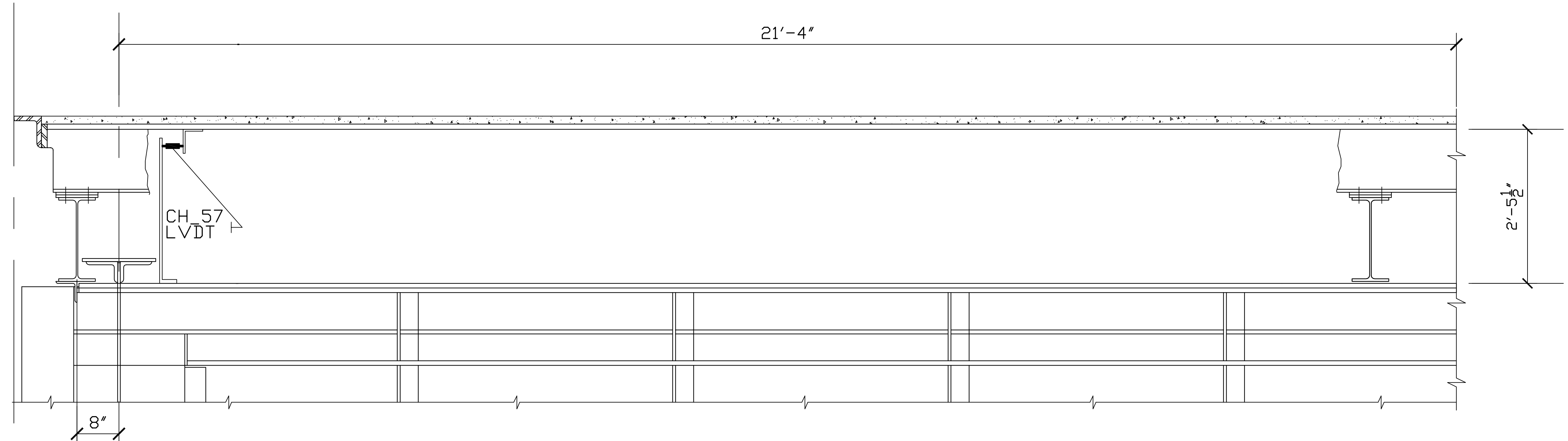
NO.	DESCRIPTION	DATE	BY
1	INITIAL SUBMITTAL	??/??	HNM

DESIGNED BY:	RJC & HNM
DRAWN BY:	HNM
CHECKED BY:	RJC
SCALE:	1/16" = 1'-0"
DATE:	5/12/05
PROJECT NO.:	526701
SHEET TITLE:	

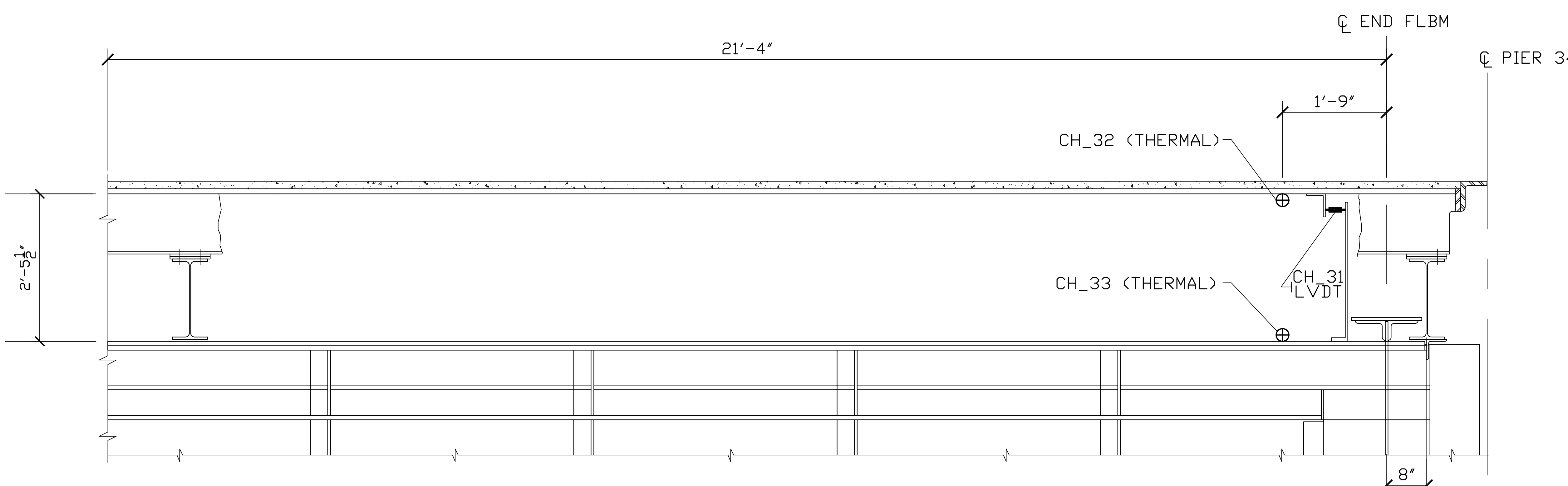
SHEET TITLE

SHEET NO.:

1 of 6



SECTION A-A
LOOKING EAST
SCALE: 1/2"=1'-0"



SECTION B-B
LOOKING EAST
SCALE: 1/2"=1'-0"

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PROJECT:

THROGS NECK OVER THE EAST RIVER NEW YORK, NY

SHEET NOTES:

SPAN 35

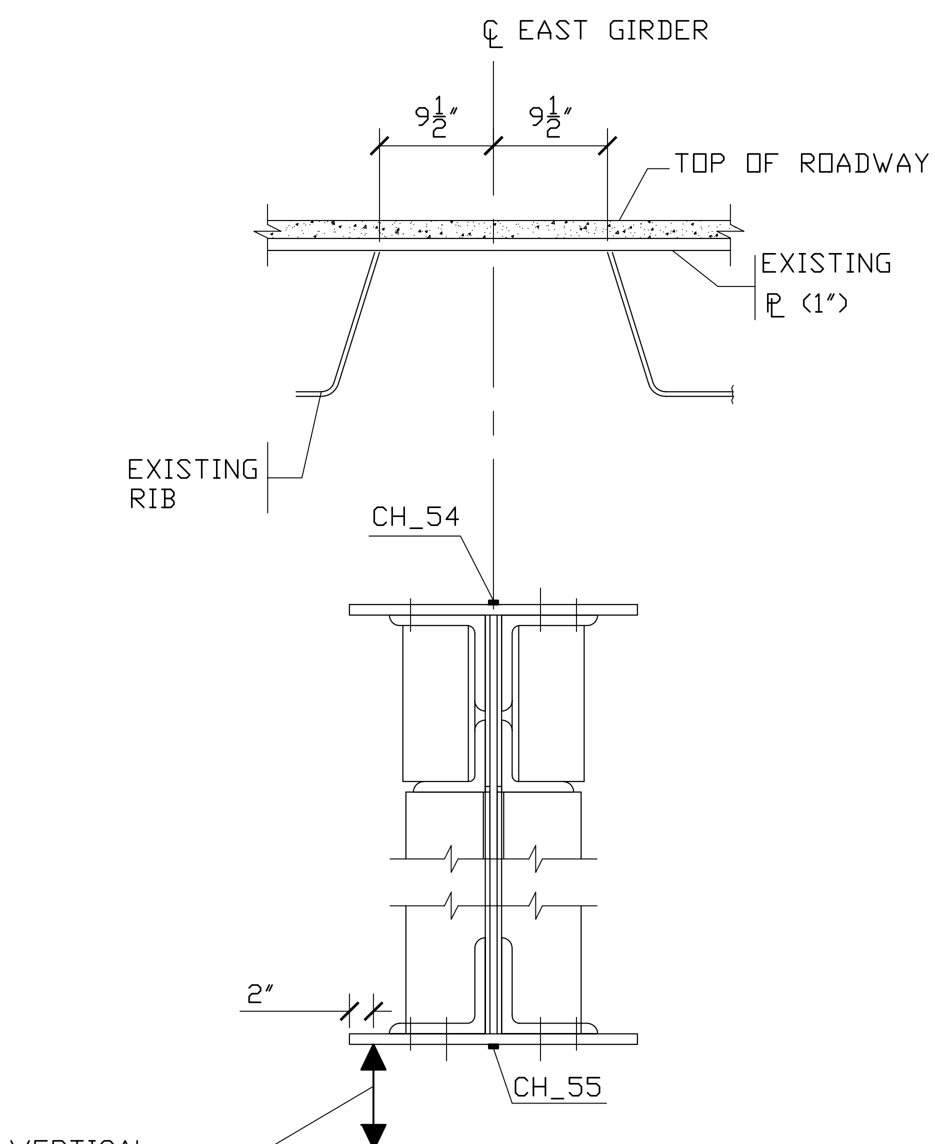
NO.	DESCRIPTION	DATE	BY
1	INITIAL SUBMITTAL	??/??	

DESIGNED BY:	RJC & HNM
DRAWN BY:	HNM
CHECKED BY:	RJC
SCALE:	1/2" = 1'-0"
DATE:	5/12/05
PROJECT NO.:	526701
SHEET TITLE:	

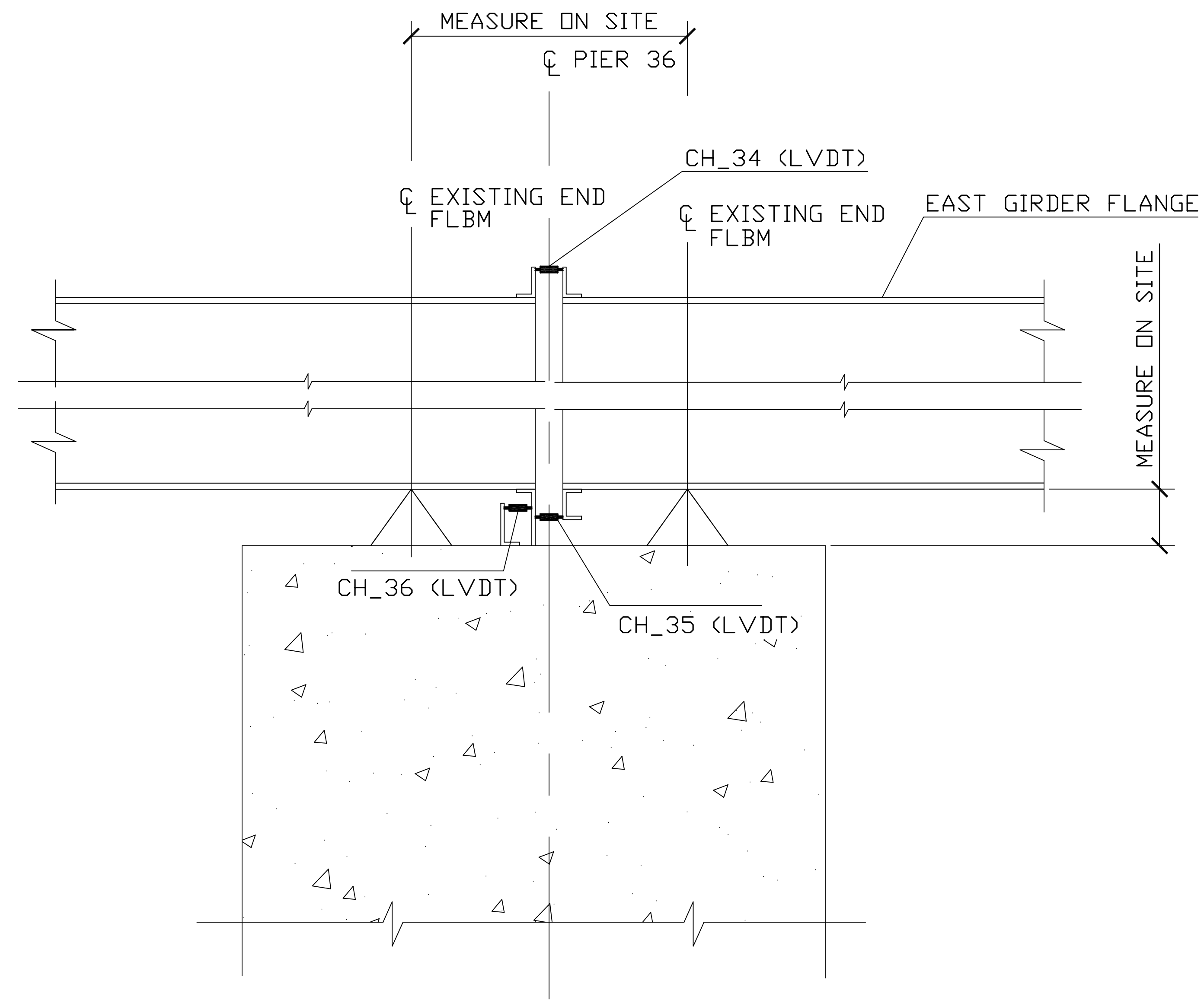
SHEET TITLE

SHEET NO.:

2 OF 6



SECTION D-D
LOOKING SOUTH
SCALE: 3/4"=1'-0"



SECTION E-E
LOOKING EAST
SCALE: N.T.S

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PROJECT:

THROGS NECK OVER THE EAST RIVER NEW YORK, NY

SHEET NOTES:

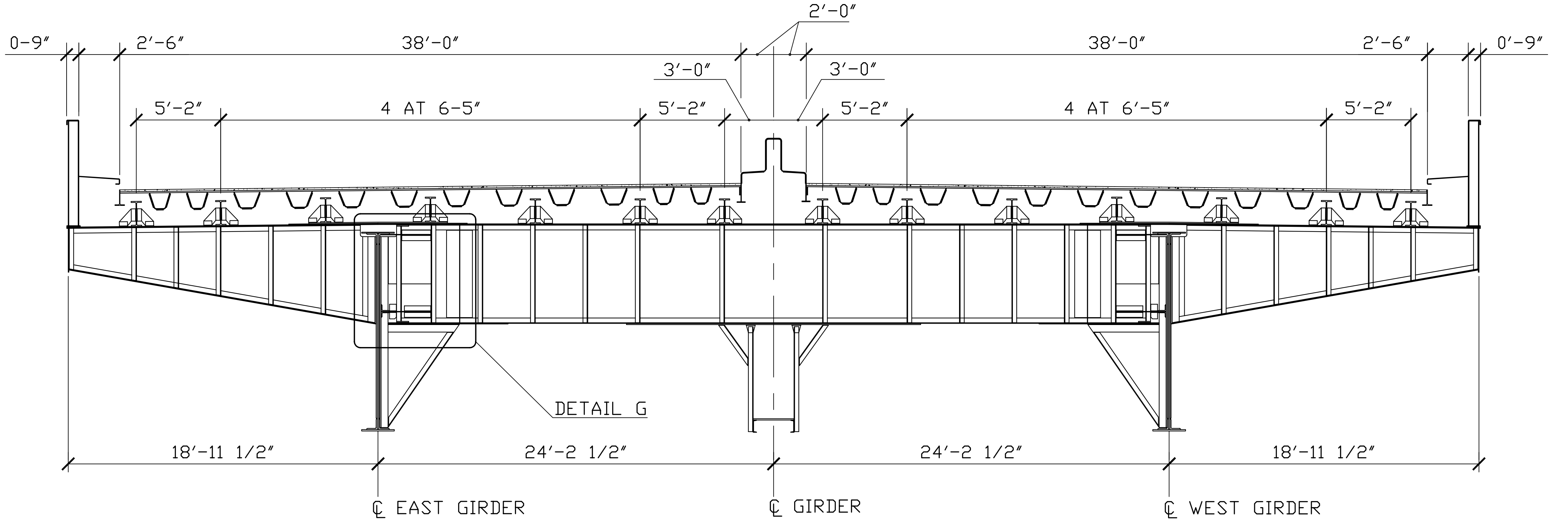
SPAN 35

NO.	DESCRIPTION	DATE	BY
1	INITIAL SUBMITTAL	?/?/??	

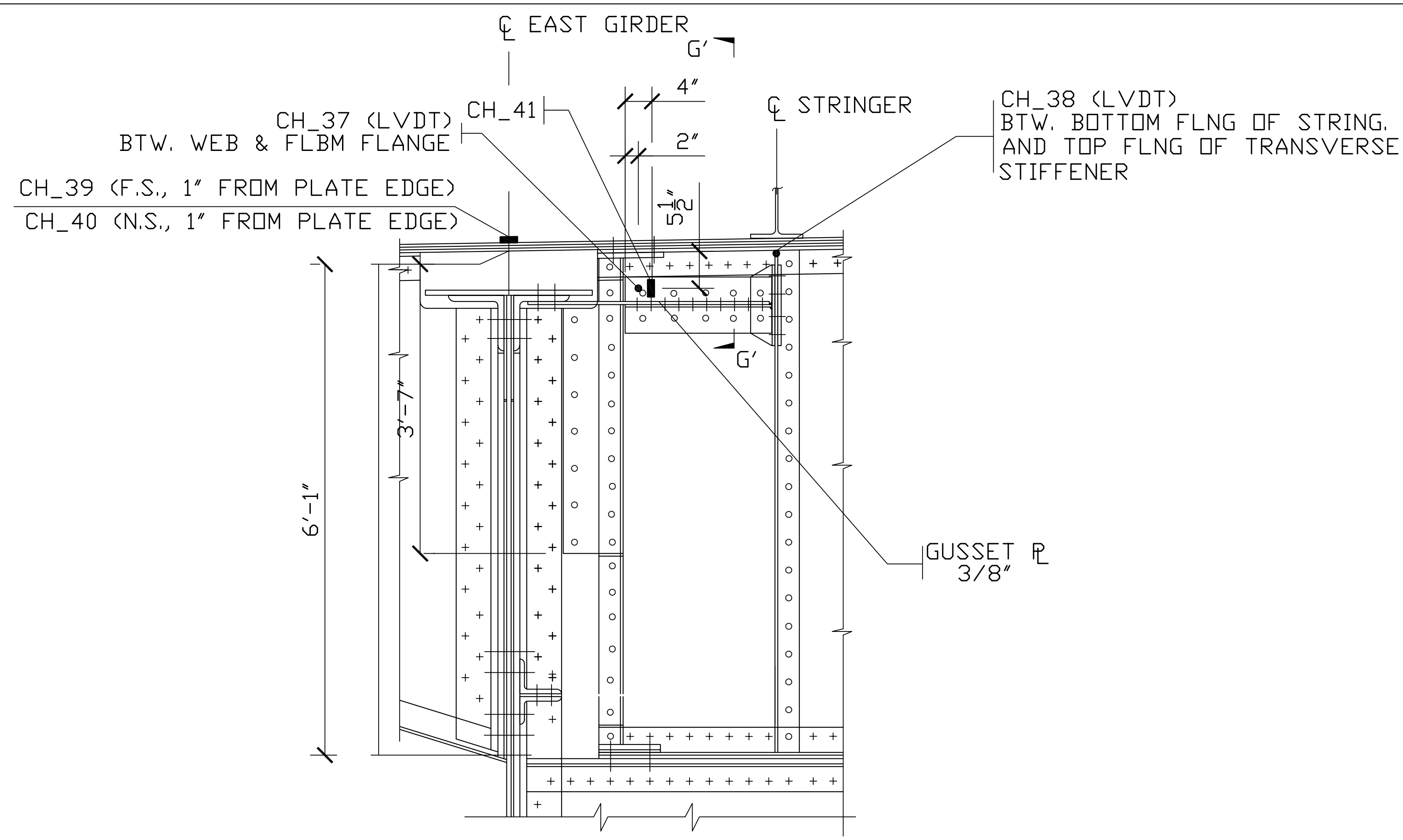
DESIGNED BY:	RJC & HNM
DRAWN BY:	HNM
CHECKED BY:	RJC
SCALE:	VARIES
DATE:	5/12/05
PROJECT NO.:	526701
SHEET TITLE:	

SHEET TITLE

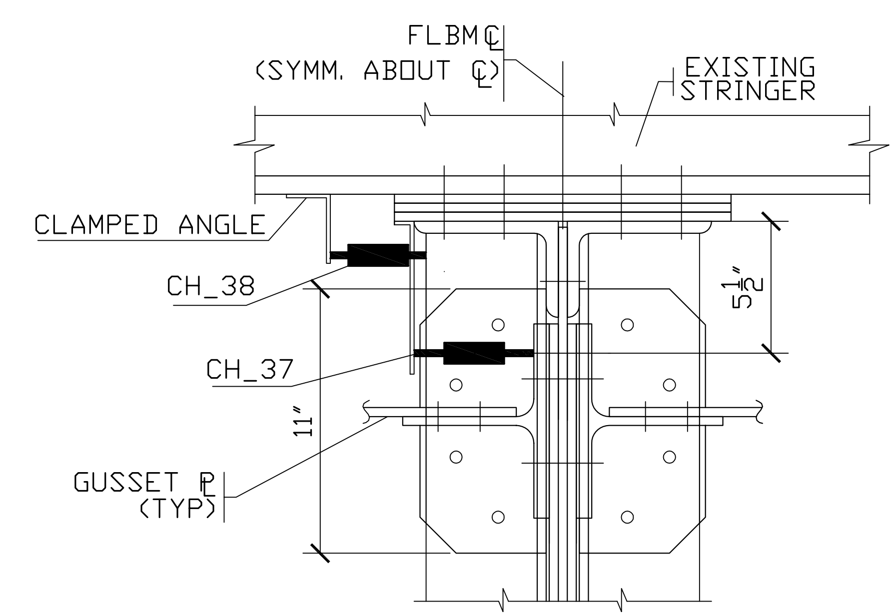
SHEET NO.:



SECTION F-F: FLOORBEAM NO. 2
VIEW LOOKING SOUTH
SCALE: 1/8"=1'-0"



DETAIL G (RETROFIT #10)
LOOKING SOUTH
SCALE: 1/2"=1'-0"



SECTION: G'-G'
LOOKING EAST
SCALE: 1 1/2"=1'-0"

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PROJECT:

THROGS NECK OVER THE EAST RIVER NEW YORK, NY

SHEET NOTES:

SPAN 35

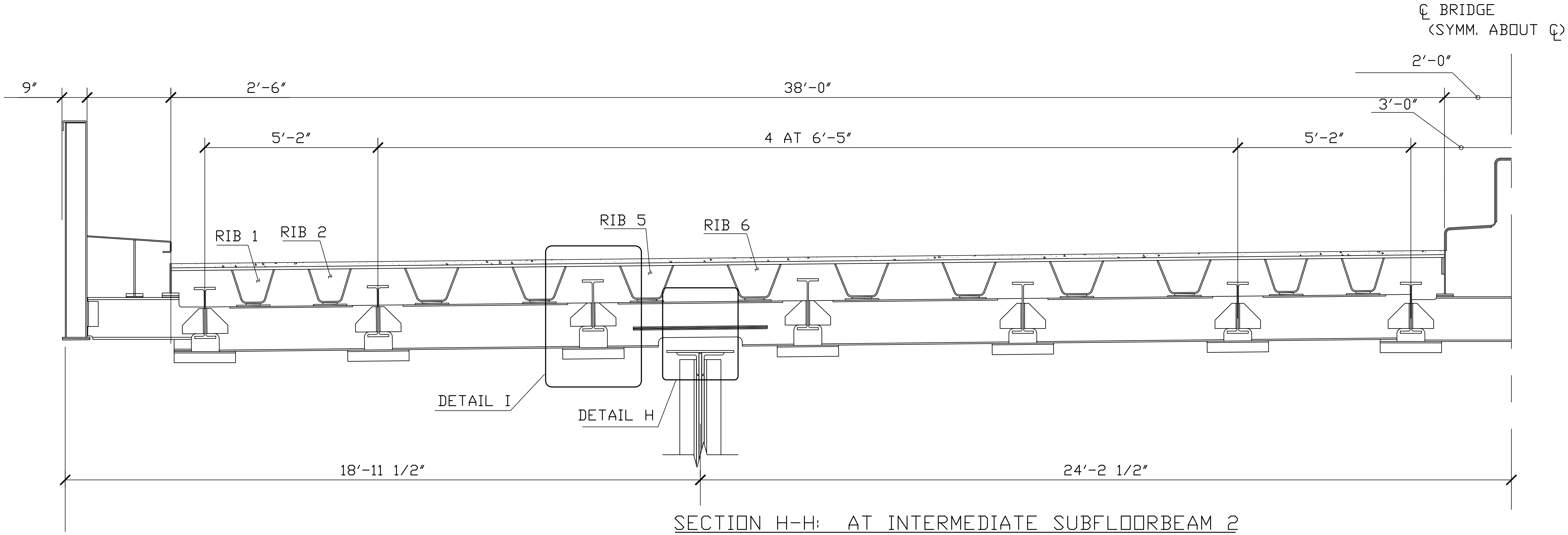
NO.	DESCRIPTION	DATE	BY
1	INITIAL SUBMITTAL	??/??/??	

DESIGNED BY:	RJC & HNM
DRAWN BY:	HNM
CHECKED BY:	RJC
SCALE:	VARIES
DATE:	5/12/05
PROJECT NO.:	526701
SHEET TITLE:	

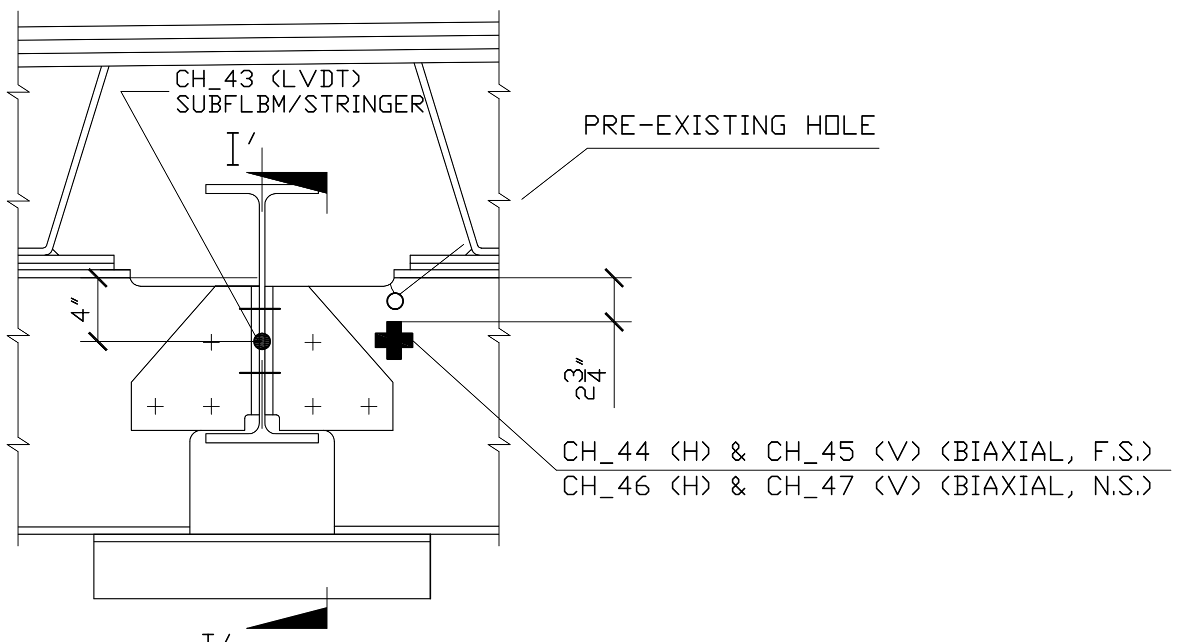
SHEET TITLE

SHEET NO.:

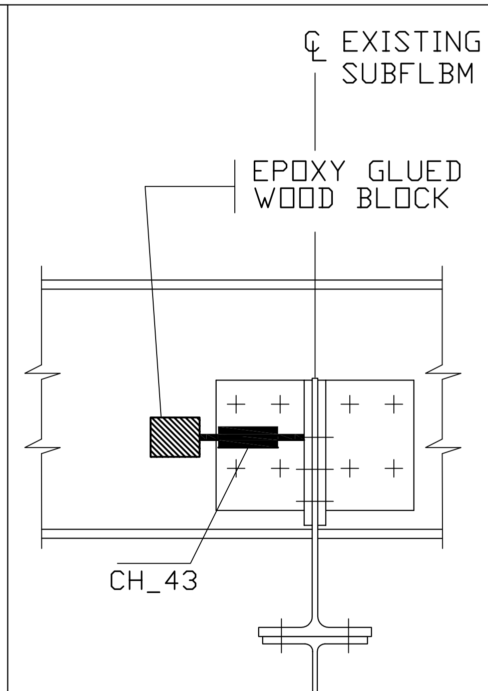
4 OF 6



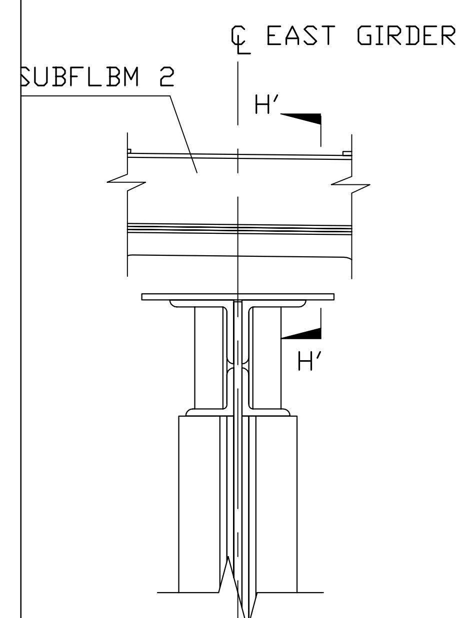
SECTION H-H: AT INTERMEDIATE SUBFLOORBEAM 2
LOOKNG SOUTH
SCALE: 5/16"=1'-0"



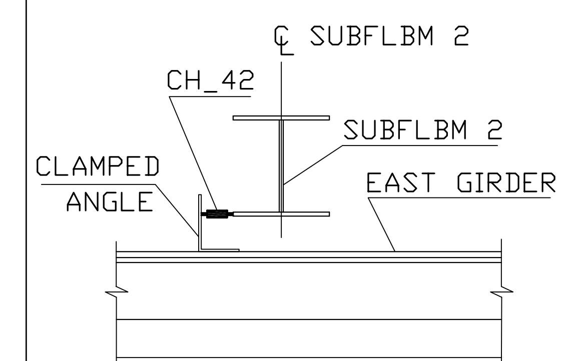
DETAIL I
LOOKING SOUTH
SCALE: 1"=1'-0"



SECTION: I'-I'
LOOKING EAST
SCALE: 1"=1'-0"



DETAIL H
LOOKING SOUTH
SCALE: 1/2"=1'-0"



SECTION H'-H'
LOOKING EAST
SCALE: 1/2"=1'-0"

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PROJECT:

THROGS NECK OVER THE EAST RIVER NEW YORK, NY

SHEET NOTES:

SPAN 35

NO.	DESCRIPTION	DATE	BY
1	INITIAL SUBMITTAL	?/?/??	

DESIGNED BY:	RJC & HNM
DRAWN BY:	HNM
CHECKED BY:	RJC
SCALE:	VARIES
DATE:	5/12/05
PROJECT NO.:	526701
SHEET TITLE:	

SHEET TITLE

SHEET NO.:

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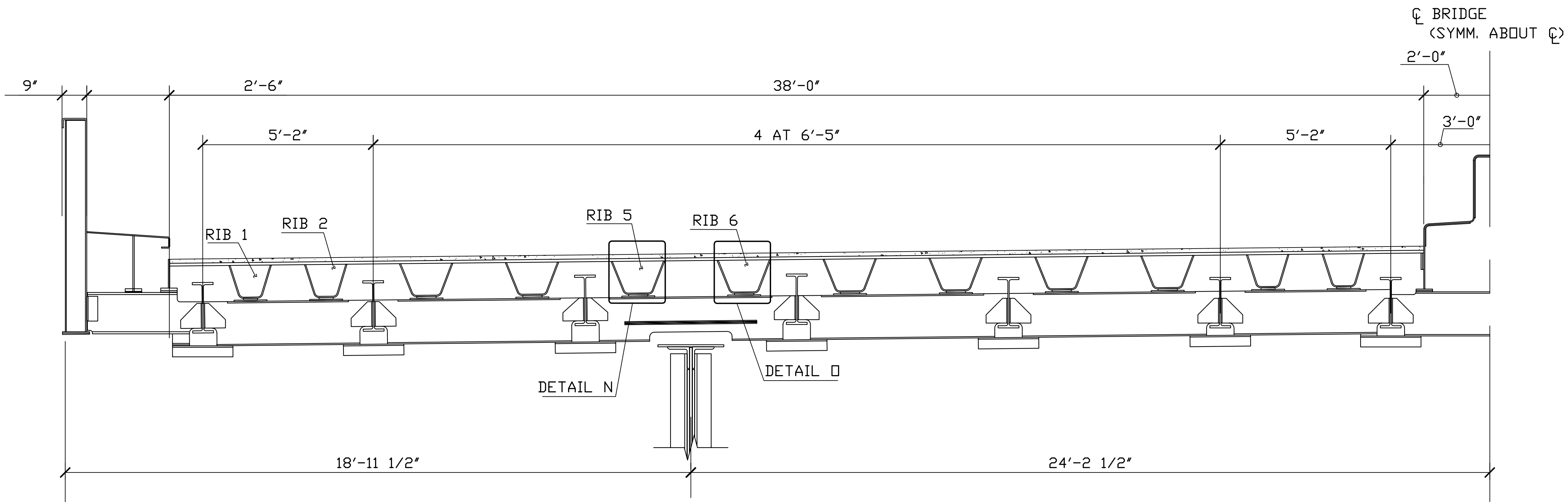
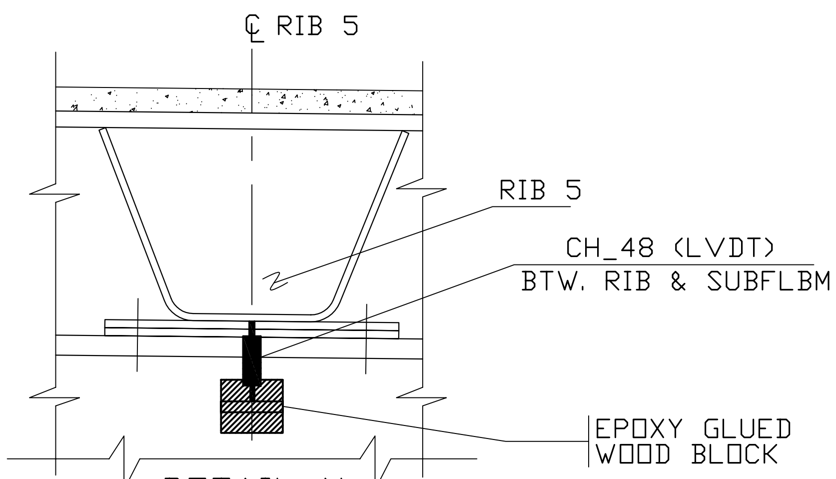
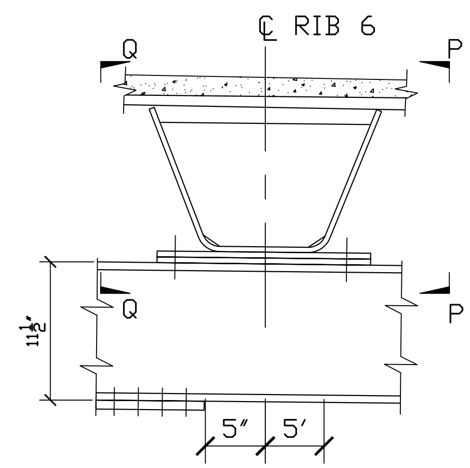


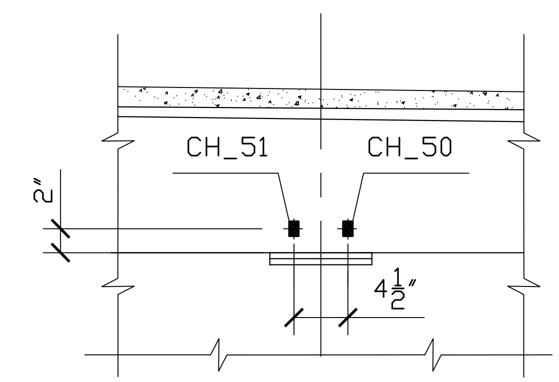
SECTION H-H: AT INTERMEDIATE SUBFLOORBEAM 2
LOOKNG SOUTH
SCALE: 5/16"=1'-0"



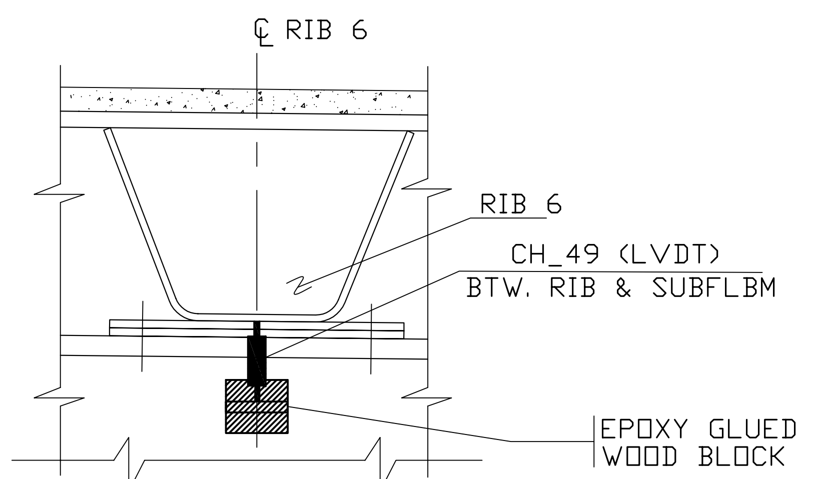
DETAIL N
LOOKING SOUTH
SCALE: 1"=1'-0"



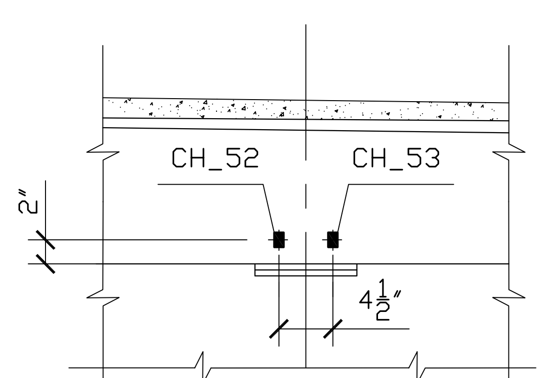
DETAIL O
LOOKING SOUTH
SCALE: 3/4"=1'-0"



SECTION P-P (WITHOUT BACKING PLATE)
LOOKING EAST
SCALE: 3/4"=1'-0"



DETAIL N
LOOKING SOUTH
SCALE: 1"=1'-0"



SECTION Q-Q (WITHOUT BACKING PLATE)
LOOKING WEST
SCALE: 3/4"=1'-0"

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PROJECT:

THROGS NECK OVER THE EAST RIVER NEW YORK, NY

SHEET NOTES:

SPAN 35

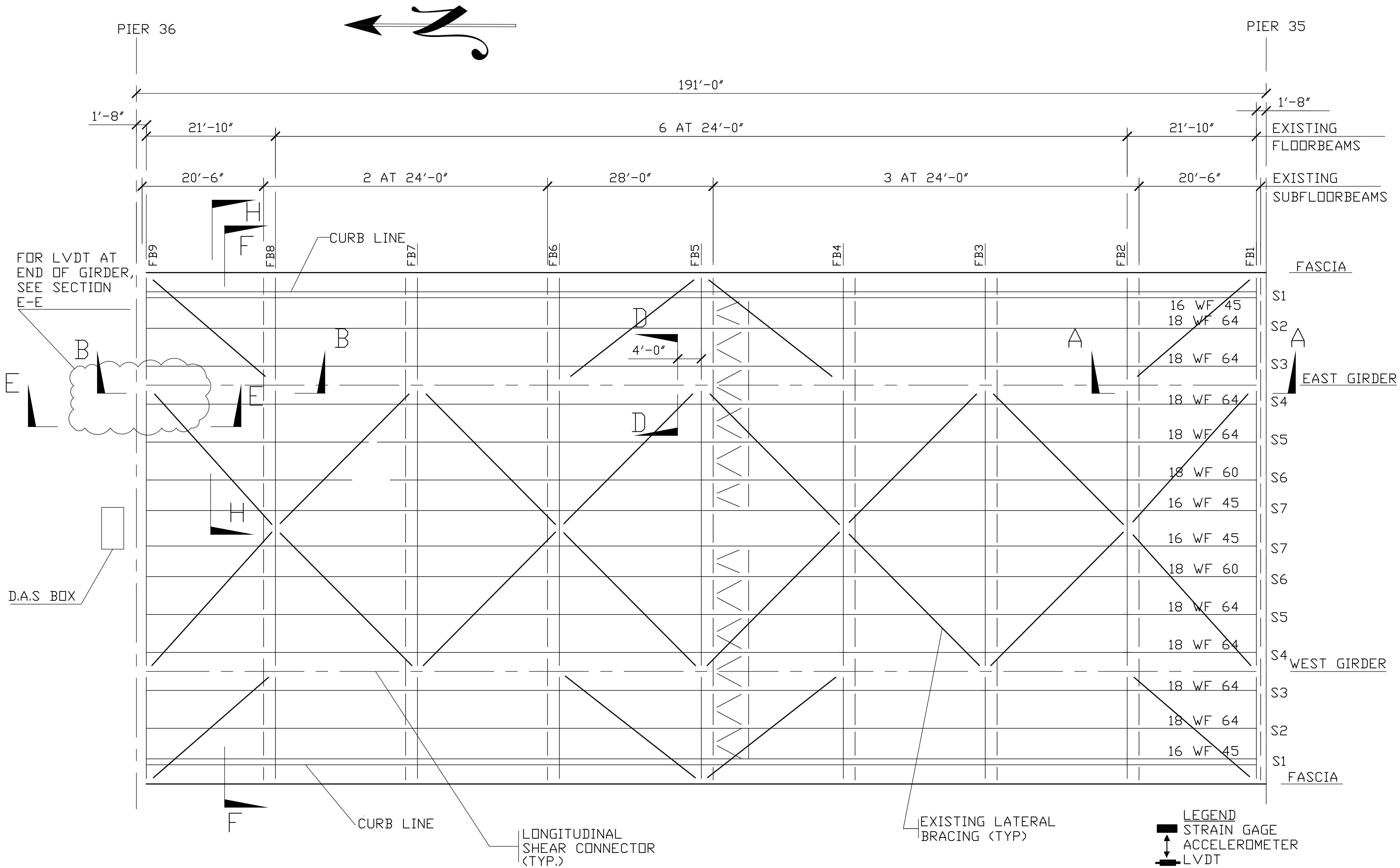
NO.	DESCRIPTION	DATE	BY
1	INITIAL SUBMITTAL	??/??/??	

DESIGNED BY:	RJC & HNM
DRAWN BY:	HNM
CHECKED BY:	RJC
SCALE:	VARIES
DATE:	5/12/05
PROJECT NO.:	526701
SHEET TITLE:	

SHEET TITLE

SHEET NO.:

6 OF 6



CHANNEL PLAN LAYOUT (SPAN 36)

SCALE: 1/16"=1'-0"

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PROJECT:

THROGS NECK OVER THE EAST RIVER NEW YORK, NY

SHEET NOTES:

SPAN 36

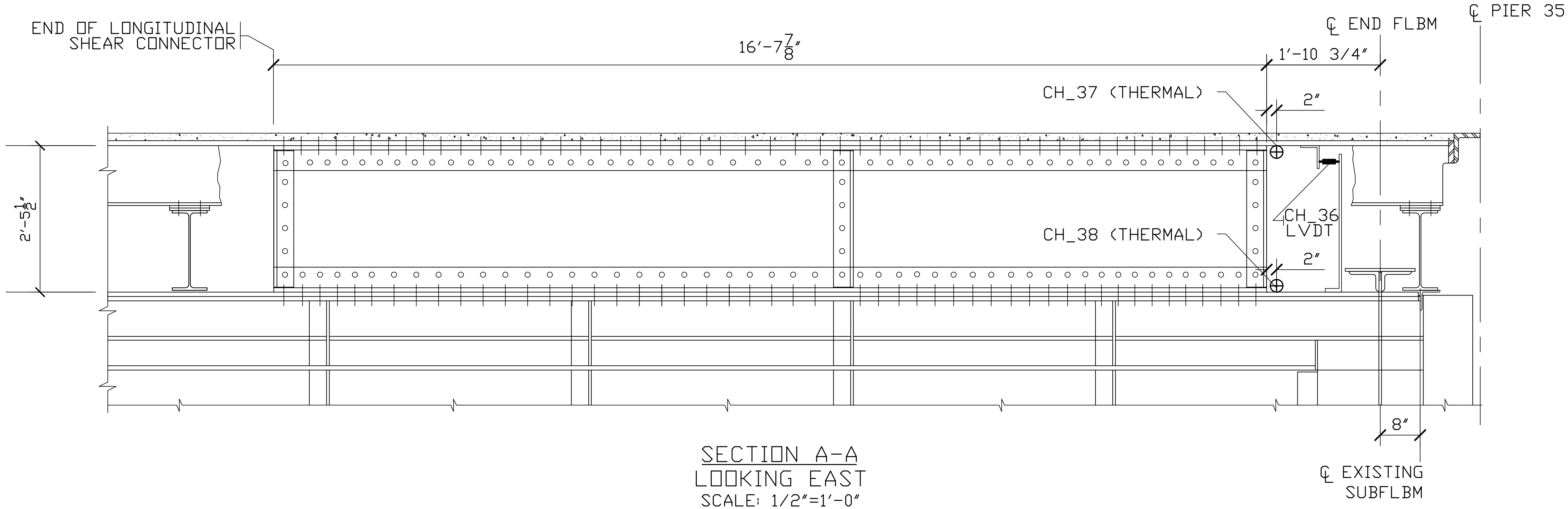
NO.	DESCRIPTION	DATE	BY
1	INITIAL SUBMITTAL	??/??/	

DESIGNED BY: RJC & HNM
DRAWN BY: HNM
CHECKED BY: RJC
SCALE: 1/8" = 1'-0"
DATE: 5/12/05
PROJECT NO.: 526701
SHEET TITLE:

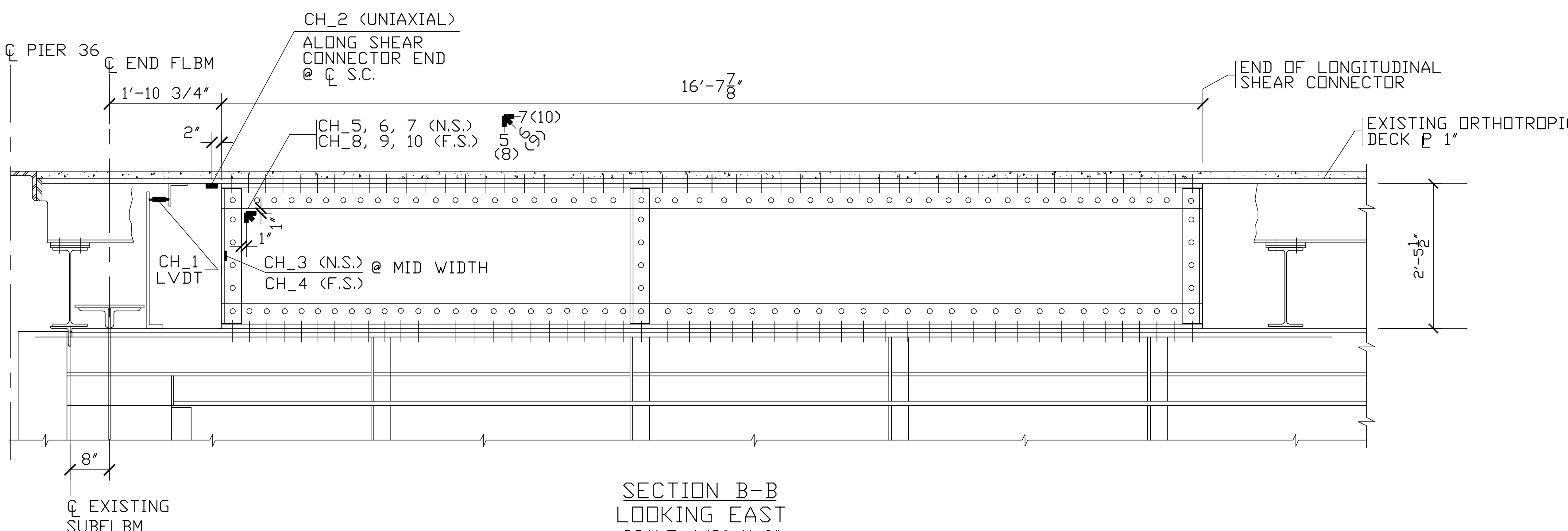
SHEET TITLE

SHEET NO.:

1 OF 6



SECTION A-A
LOOKING EAST
SCALE: 1/2"=1'-0"



SECTION B-B
LOOKING EAST
SCALE: 1/2"=1'-0"

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PROJECT:

THROGS NECK OVER THE EAST RIVER NEW YORK, NY

SHEET NOTES:

SPAN 36

NO.	DESCRIPTION	DATE	BY
1	INITIAL SUBMITTAL	?/?/??	

DESIGNED BY:	RJC & HNM
DRAWN BY:	HNM
CHECKED BY:	RJC
SCALE:	1/2" = 1'-0"
DATE:	5/12/05
PROJECT NO.:	526701
SHEET TITLE:	

SHEET TITLE

SHEET NO.:

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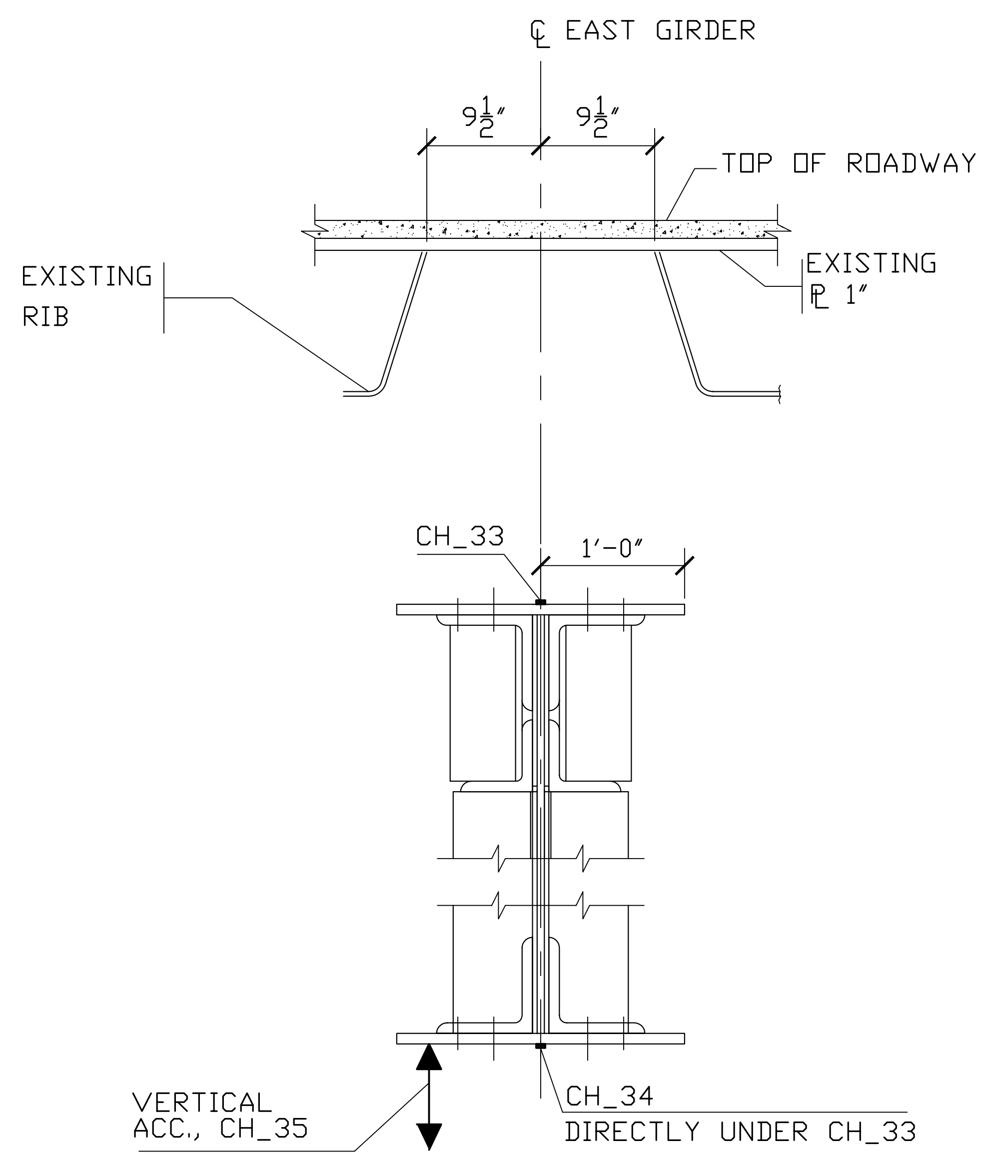
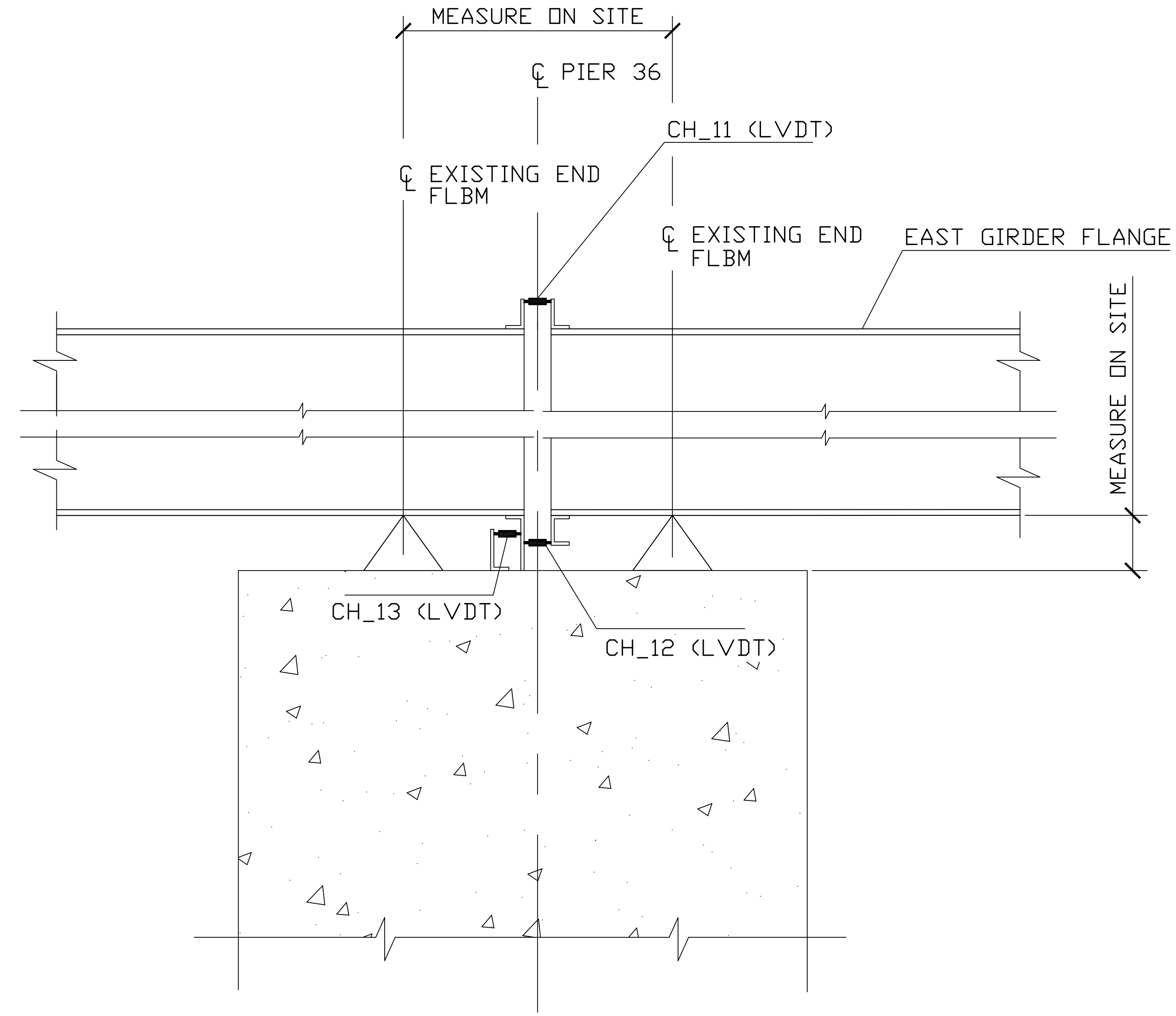


SECTION D-D
LOOKING NORTH
SCALE: 3/4"=1'-0"



SECTION E-E
LOOKING EAST
SCALE: N.T.S

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PROJECT:

THROGS NECK OVER THE EAST RIVER NEW YORK, NY

SHEET NOTES:

SPAN 36

NO.	DESCRIPTION	DATE	BY
1	INITIAL SUBMITTAL	?/?/??	

DESIGNED BY: RJC & HNM
DRAWN BY: HNM
CHECKED BY: RJC
SCALE: VARIES
DATE: 5/12/05
PROJECT NO.: 526701
SHEET TITLE:

SHEET TITLE

SHEET NO.:

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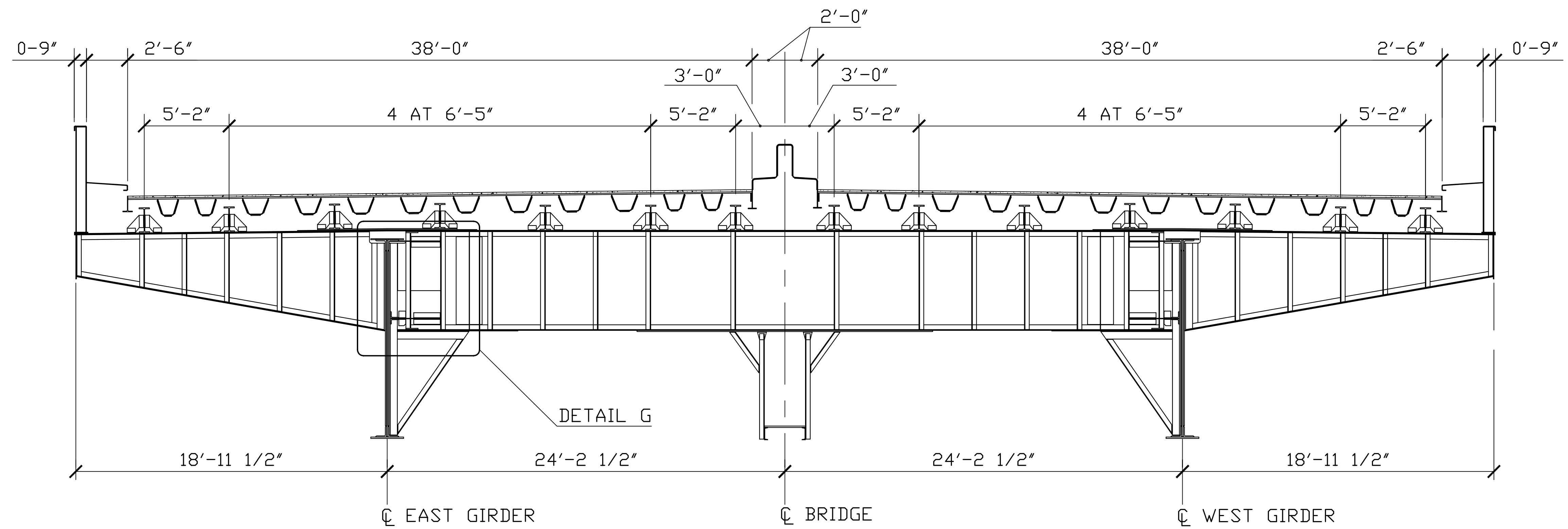
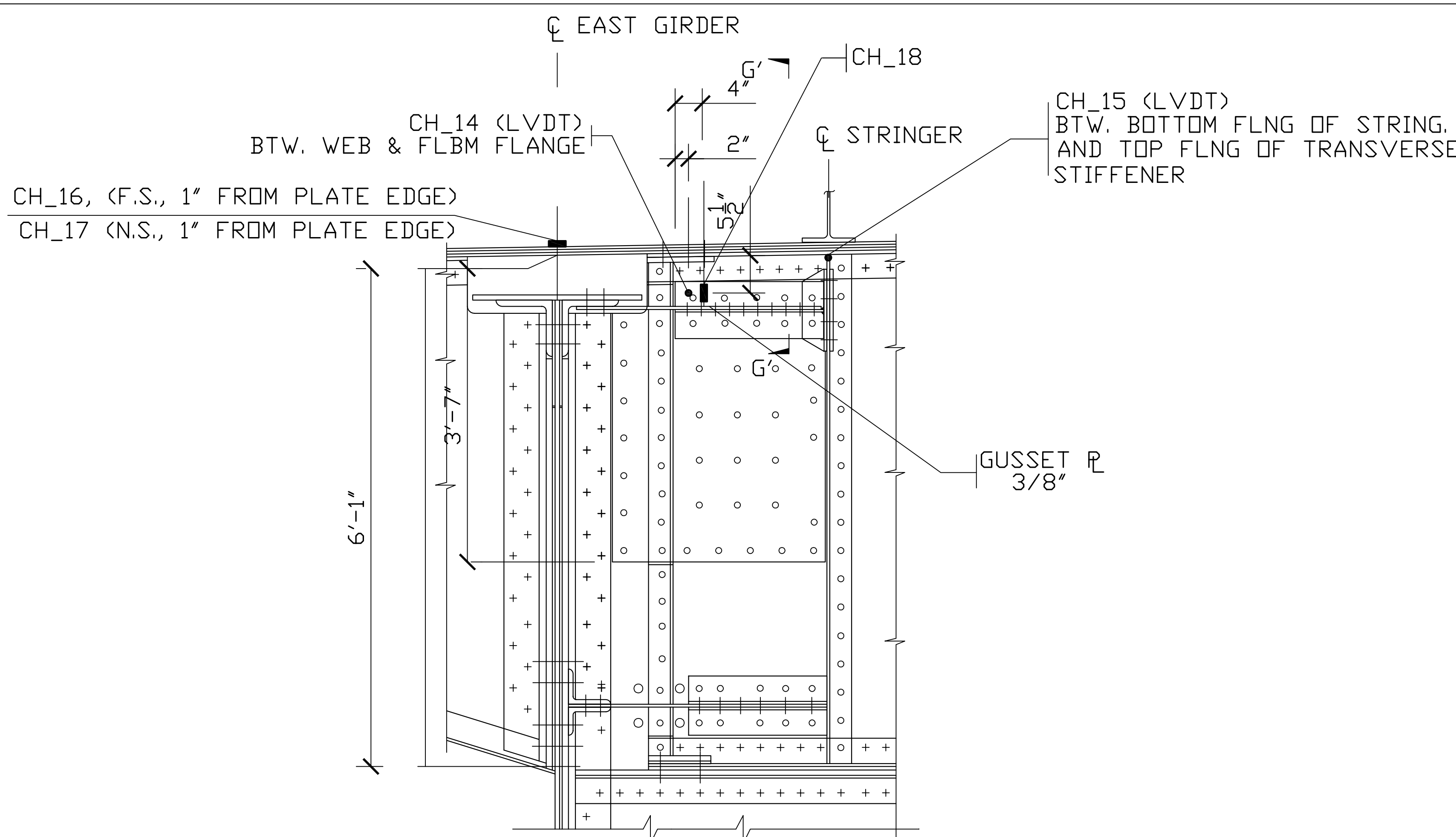
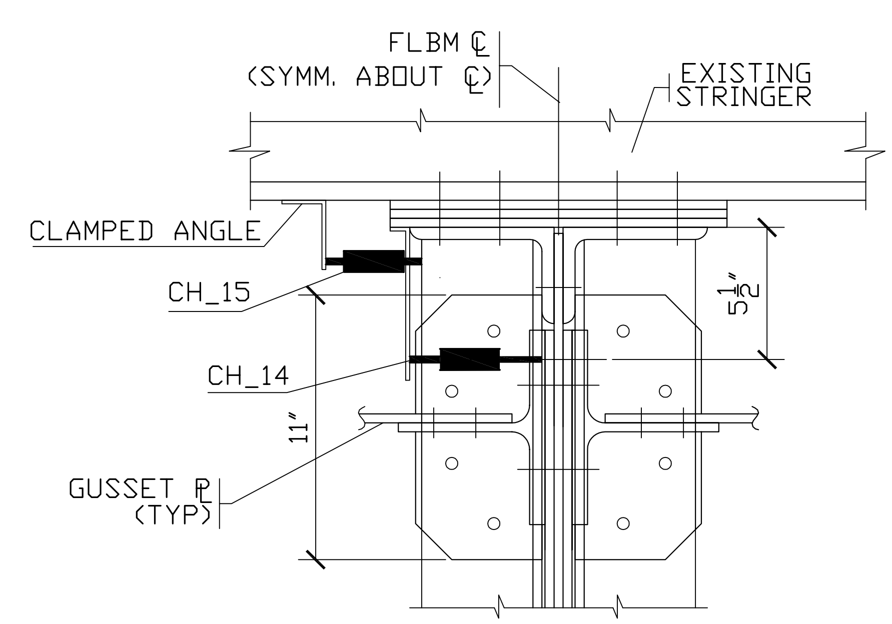


SECTION F-F: FLOORBEAM NO. 8
VIEW LOOKING SOUTH
SCALE: 1/8"=1'-0"



DETAIL G
LOOKING SOUTH
SCALE: 1/2"=1'-0"



SECTION: G'-G'
LOOKING EAST
SCALE: 1 1/2"=1'-0"

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PROJECT:

THROGS NECK OVER THE EAST RIVER NEW YORK, NY

SHEET NOTES:

SPAN 36

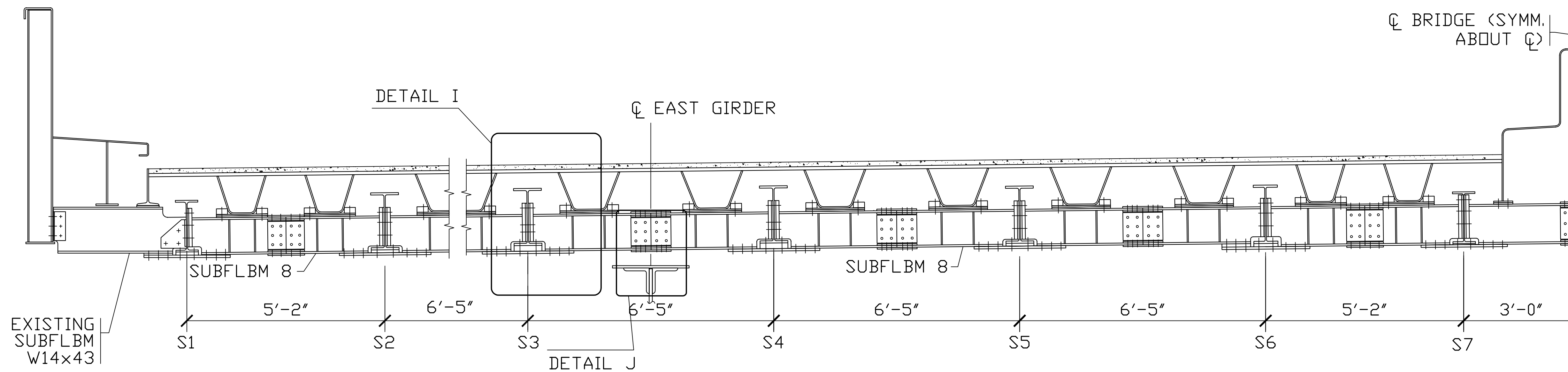
NO.	DESCRIPTION	DATE	BY
1	INITIAL SUBMITTAL	??/??/??	

DESIGNED BY:	RJC & HNM
DRAWN BY:	HNM
CHECKED BY:	RJC
SCALE:	1/8" = 1'-0"
DATE:	5/12/05
PROJECT NO.:	526701
SHEET TITLE:	

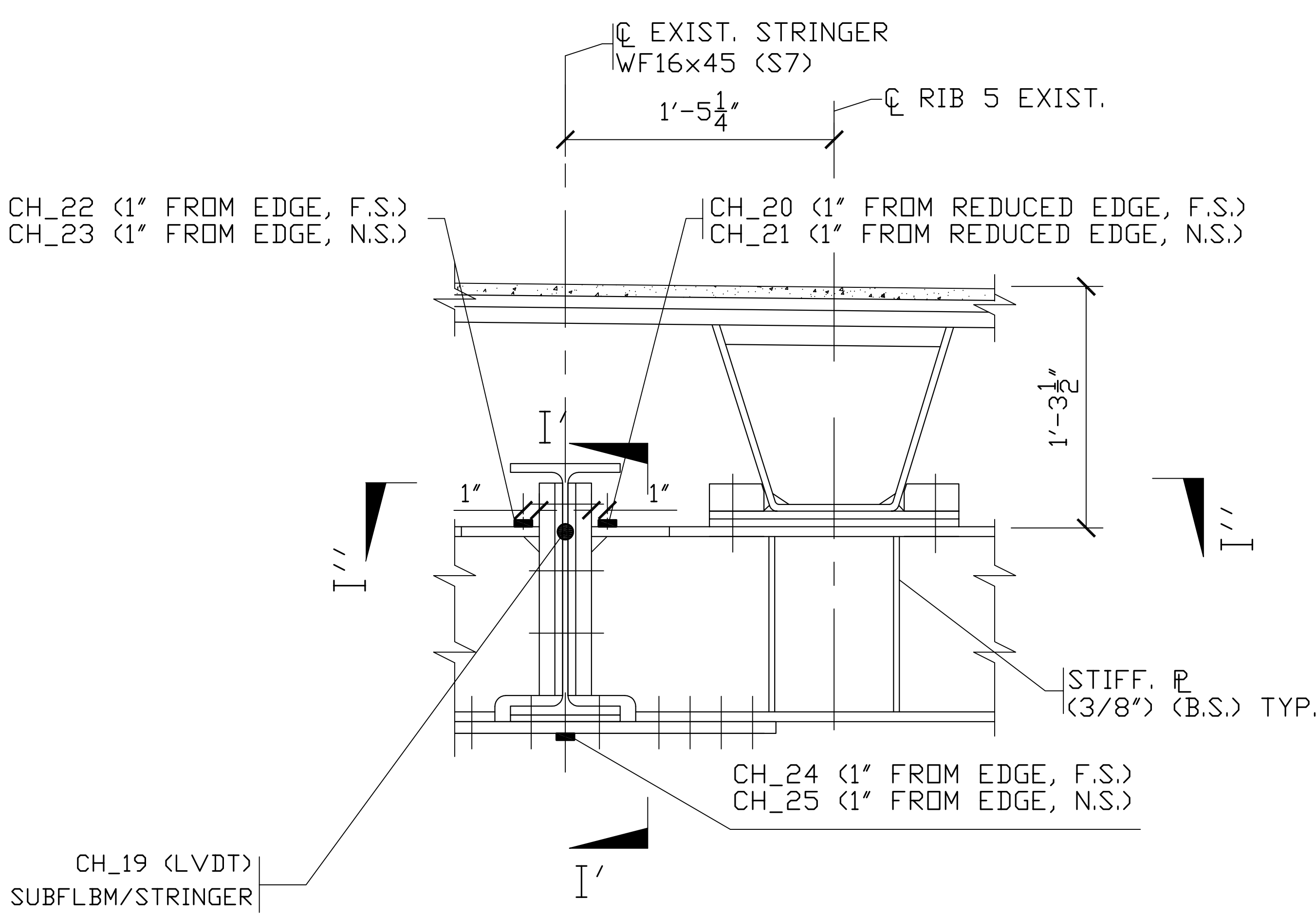
SHEET TITLE

SHEET NO.:

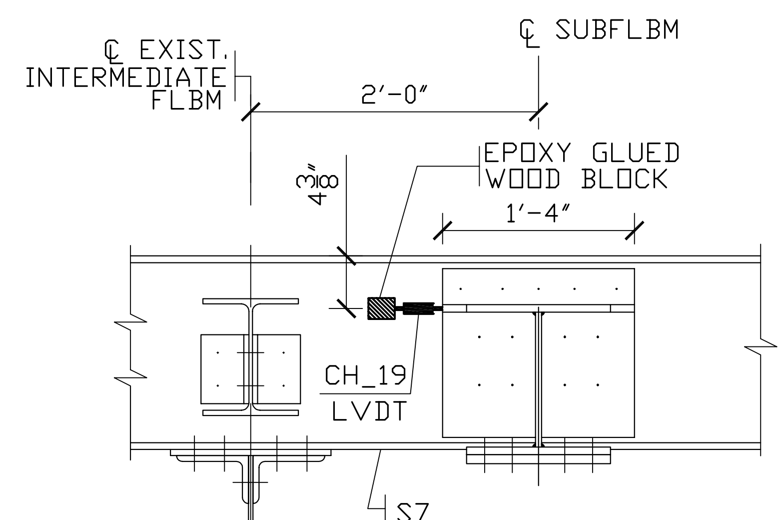
4 OF 6



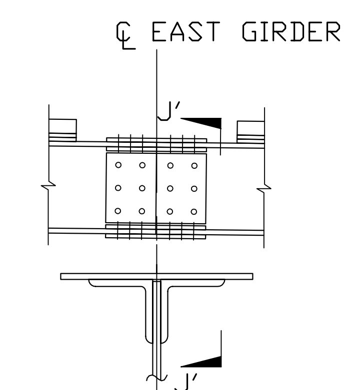
SECTION H-H: AT INTERMEDIATE SUBFLOORBEAM 8
LOOKING SOUTH
SCALE: 5/16"=1'-0"



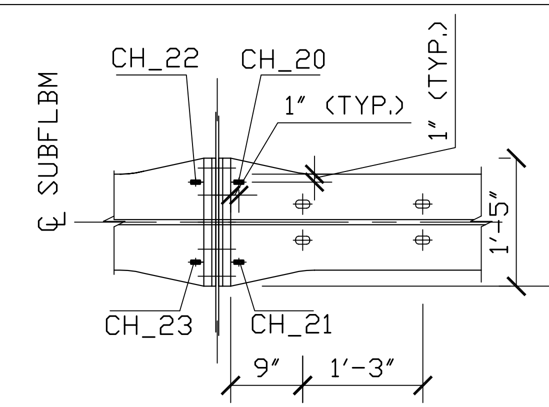
DETAIL I
LOOKING SOUTH
SCALE: 1"=1'-0"



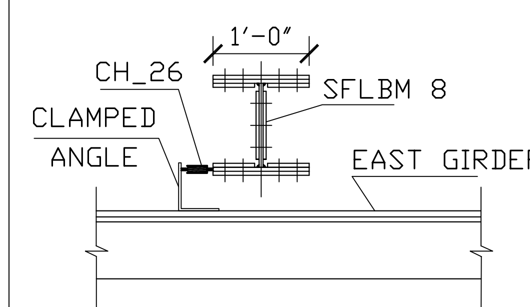
SECTION: I'-I'
LOOKING EAST
SCALE: 3/4"=1'-0"



DETAIL J
LOOKING SOUTH
SCALE: 1/2"=1'-0"



SECTION I''-I''
PLAN VIEW
SCALE: 1/2"=1'-0"



SECTION J'-J'
LOOKING EAST
SCALE: 1/2"=1'-0"

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PROJECT:

THROGS NECK OVER THE EAST RIVER NEW YORK, NY

SHEET NOTES:

SPAN 36

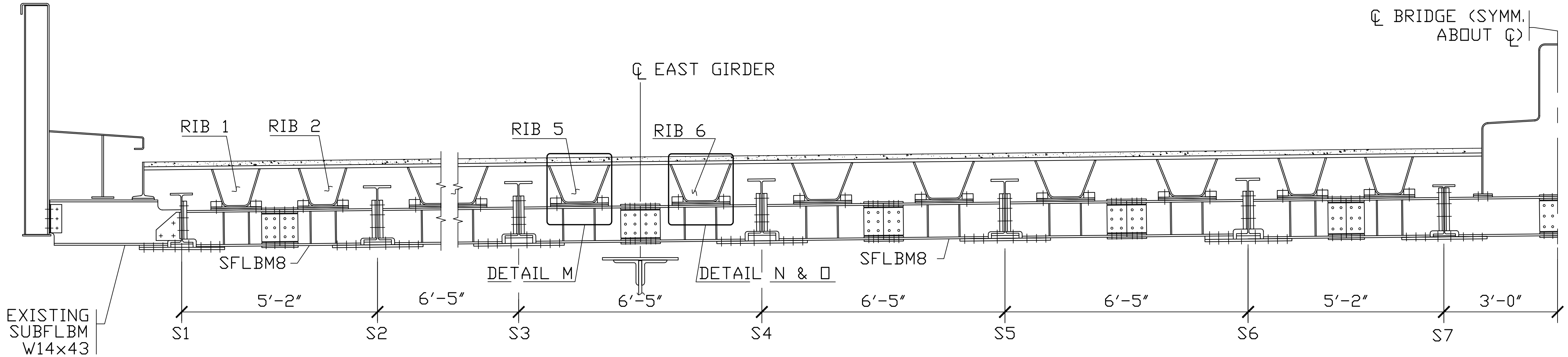
NO.	DESCRIPTION	DATE	BY
1	INITIAL SUBMITTAL	??/??/	

DESIGNED BY:	RJC & HNM
DRAWN BY:	HNM
CHECKED BY:	RJC
SCALE:	VARIES
DATE:	5/12/05
PROJECT NO.:	526701
SHEET TITLE:	

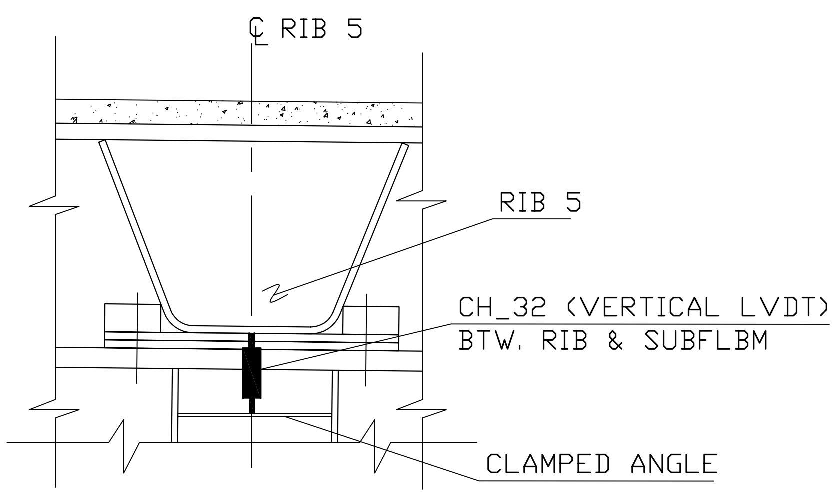
SHEET TITLE

SHEET NO.:

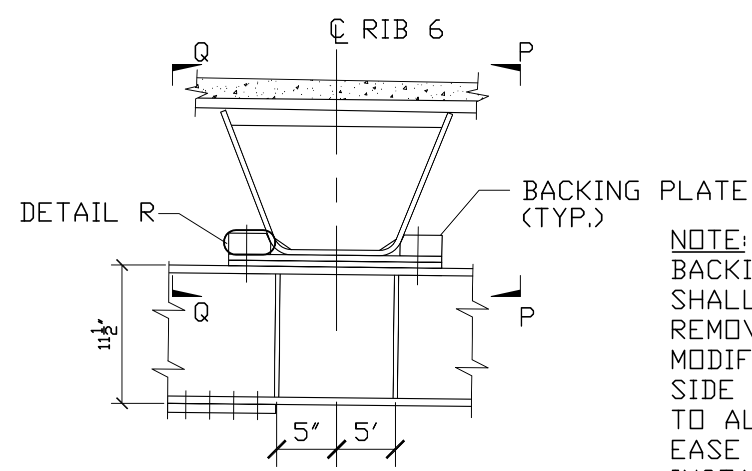
5 OF 6



SECTION H-H: AT INTERMEDIATE SUBFLOORBEAM 8
LOOKING SOUTH
SCALE: 5/16"=1'-0"

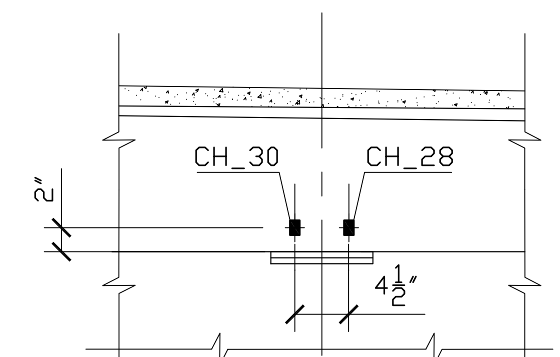


DETAIL M
LOOKING SOUTH
SCALE: 1"=1'-0"

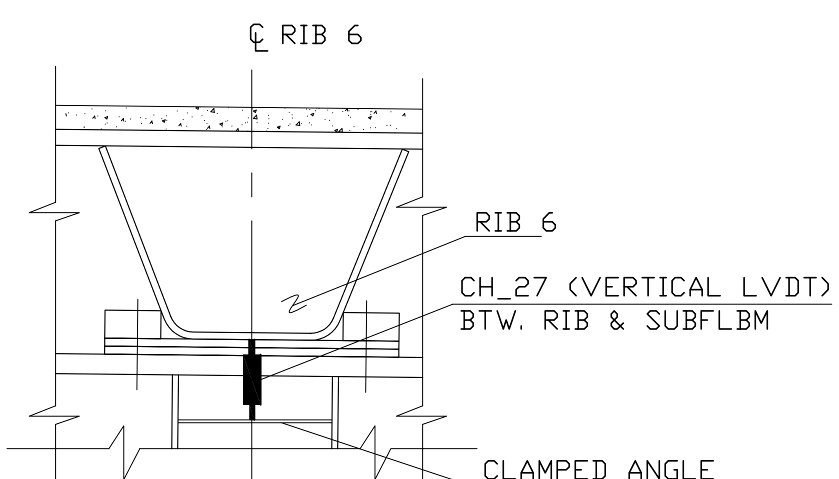


DETAIL O
LOOKING SOUTH
SCALE: 3/4"=1'-0"

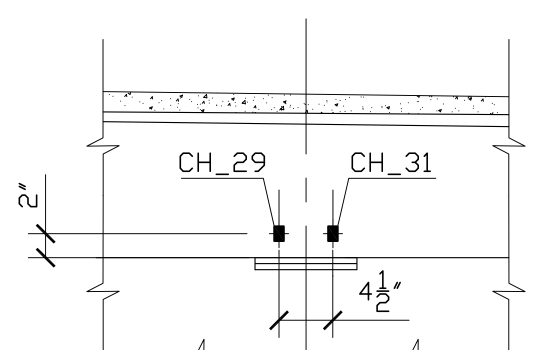
NOTE:
BACKING PLATES SHALL BE REMOVED AND MODIFIED ON EACH SIDE OF THE RIB TO ALLOW FOR EASE OF GAGE INSTALLATION AND WIRE PLACEMENT (SEE DETAIL R)



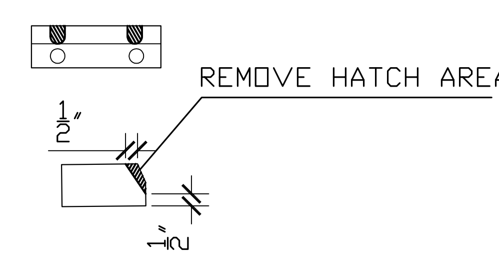
SECTION P-P
LOOKING EAST
SCALE: 3/4"=1'-0"



DETAIL N
LOOKING SOUTH
SCALE: 1"=1'-0"



SECTION Q-Q
LOOKING WEST
SCALE: 3/4"=1'-0"



DETAIL R

SCALE: 1 1/2"=1'-0"

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PROJECT:

THROGS NECK OVER THE EAST RIVER NEW YORK, NY

SHEET NOTES:

SPAN 36

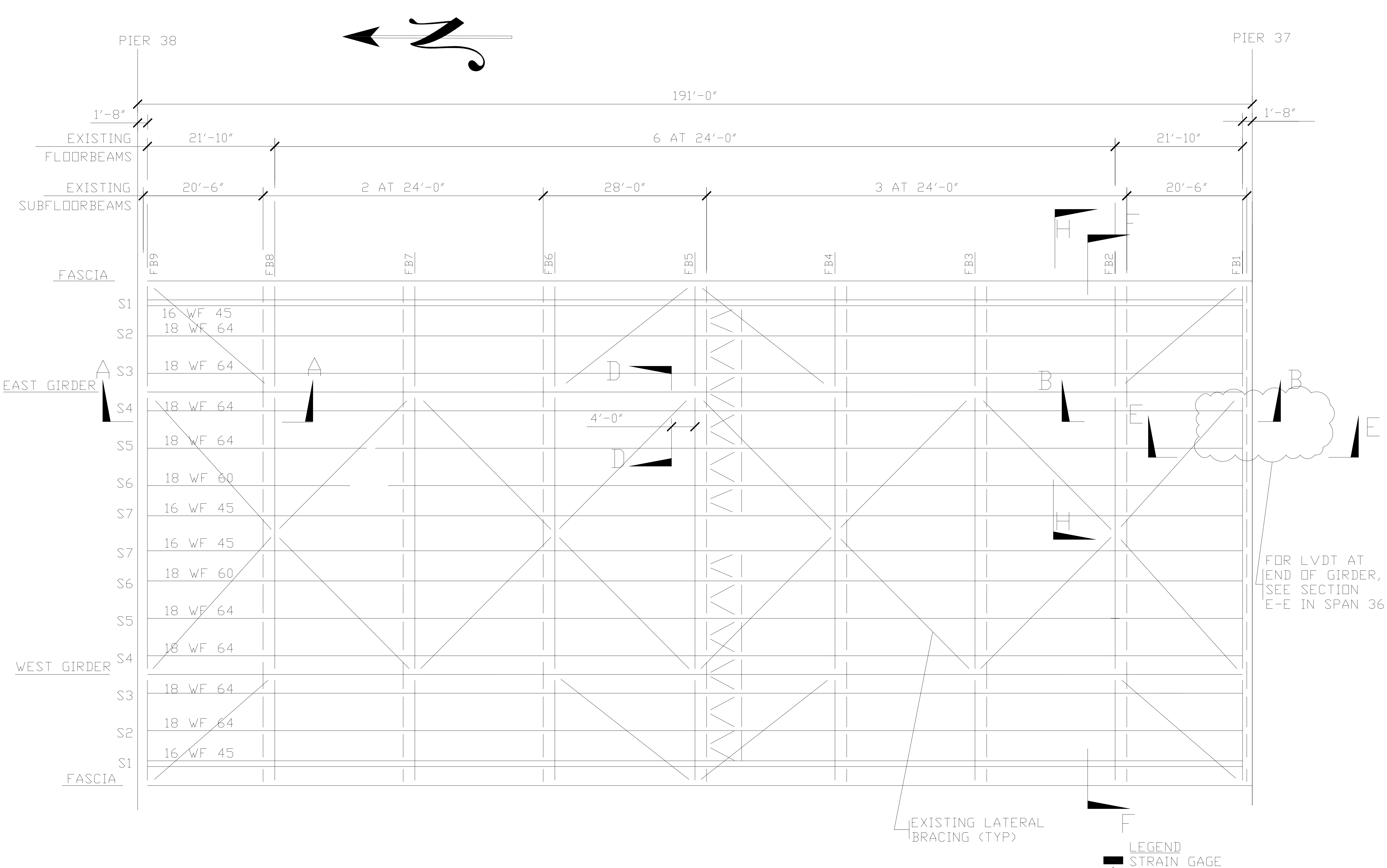
NO.	DESCRIPTION	DATE	BY
1	INITIAL SUBMITTAL	?/?/??	

DESIGNED BY: RJC & HNM
DRAWN BY: HNM
CHECKED BY: RJC
SCALE: VARIES
DATE: 5/12/05
PROJECT NO.: 526701
SHEET TITLE:

SHEET TITLE

SHEET NO.:

6 OF 6



CHANNEL PLAN LAYOUT (SPAN 38)
SCALE: 1/16"=1'-0"

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PROJECT:

THROGS NECK OVER THE EAST RIVER NEW YORK, NY

SHEET NOTES:

SPAN 38

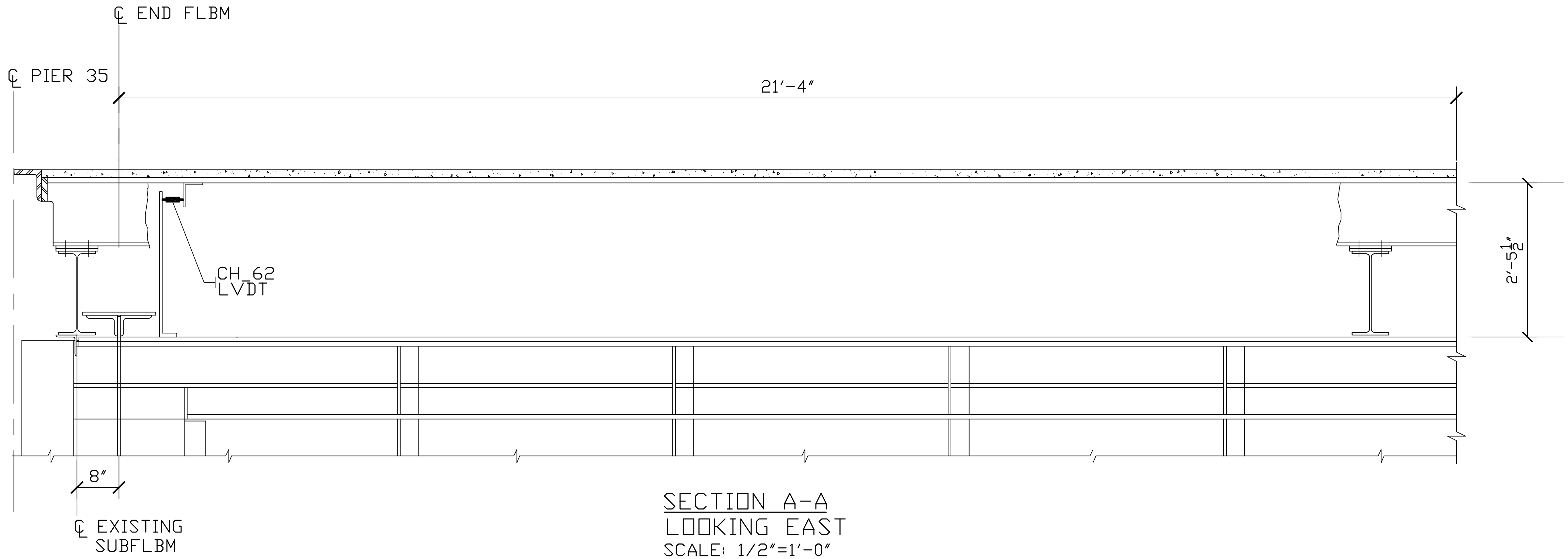
NO.	DESCRIPTION	DATE	BY
1	INITIAL SUBMITTAL	??/??	HNM

DESIGNED BY: RJC & HNM
DRAWN BY: HNM
CHECKED BY: RJC
SCALE: 1/16" = 1'-0"
DATE: 5/12/05
PROJECT NO.: 526701
SHEET TITLE:

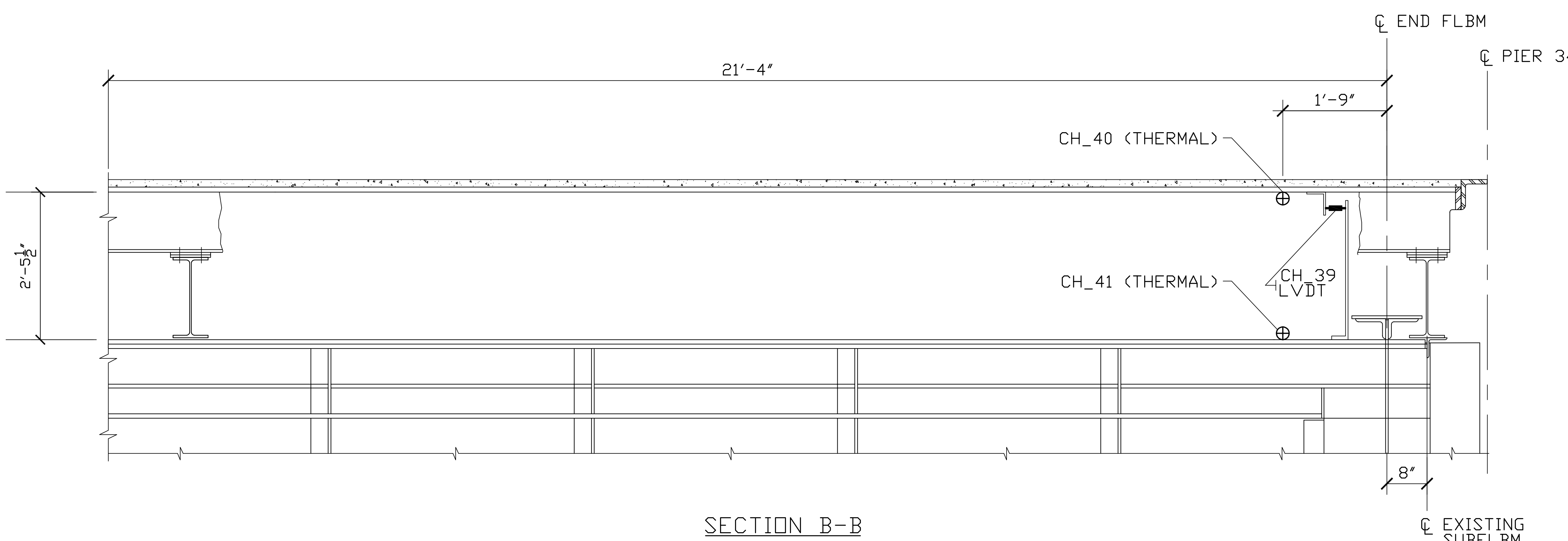
SHEET TITLE

SHEET NO.:

1 OF 6



SECTION A-A
LOOKING EAST
SCALE: 1/2"=1'-0"



SECTION B-B
LOOKING EAST
SCALE: 1/2"=1'-0"

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PROJECT:

THROGS NECK OVER THE EAST RIVER
NEW YORK, NY

SHEET NOTES:

SPAN 38

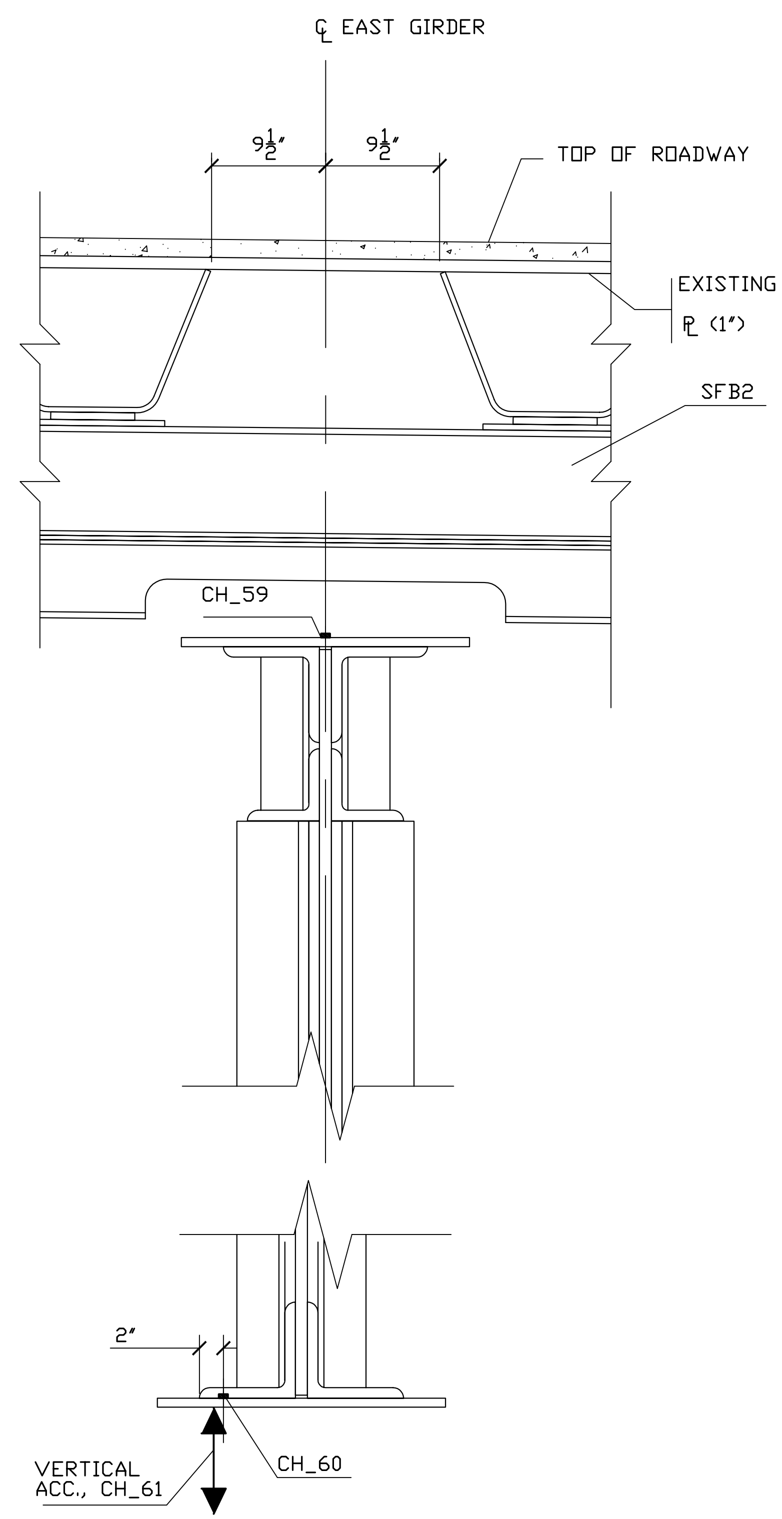
NO.	DESCRIPTION	DATE	BY
1	INITIAL SUBMITTAL	?/?/??	

DESIGNED BY:	RJC & HNM
DRAWN BY:	HNM
CHECKED BY:	RJC
SCALE:	1/2" = 1'-0"
DATE:	5/12/05
PROJECT NO.:	526701
SHEET TITLE:	

SHEET TITLE

SHEET NO.:

2 OF 6



SECTION D-D
LOOKING NORTH
SCALE: 3/4"=1'-0"

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PROJECT:

THROGS NECK OVER THE EAST RIVER NEW YORK, NY

SHEET NOTES:

SPAN 38

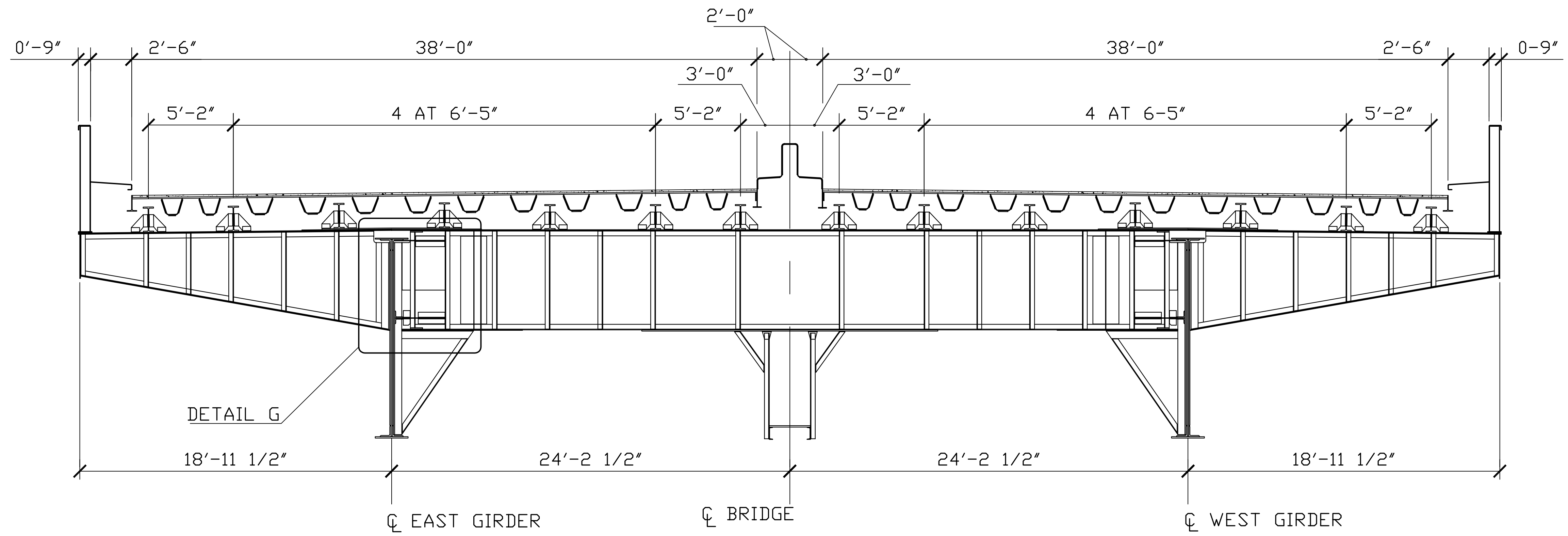
NO.	DESCRIPTION	DATE	BY
1	INITIAL SUBMITTAL	??/??/??	

DESIGNED BY:	RJC & HNM
DRAWN BY:	HNM
CHECKED BY:	RJC
SCALE:	3/4" = 1'-0"
DATE:	5/12/05
PROJECT NO.:	526701
SHEET TITLE:	

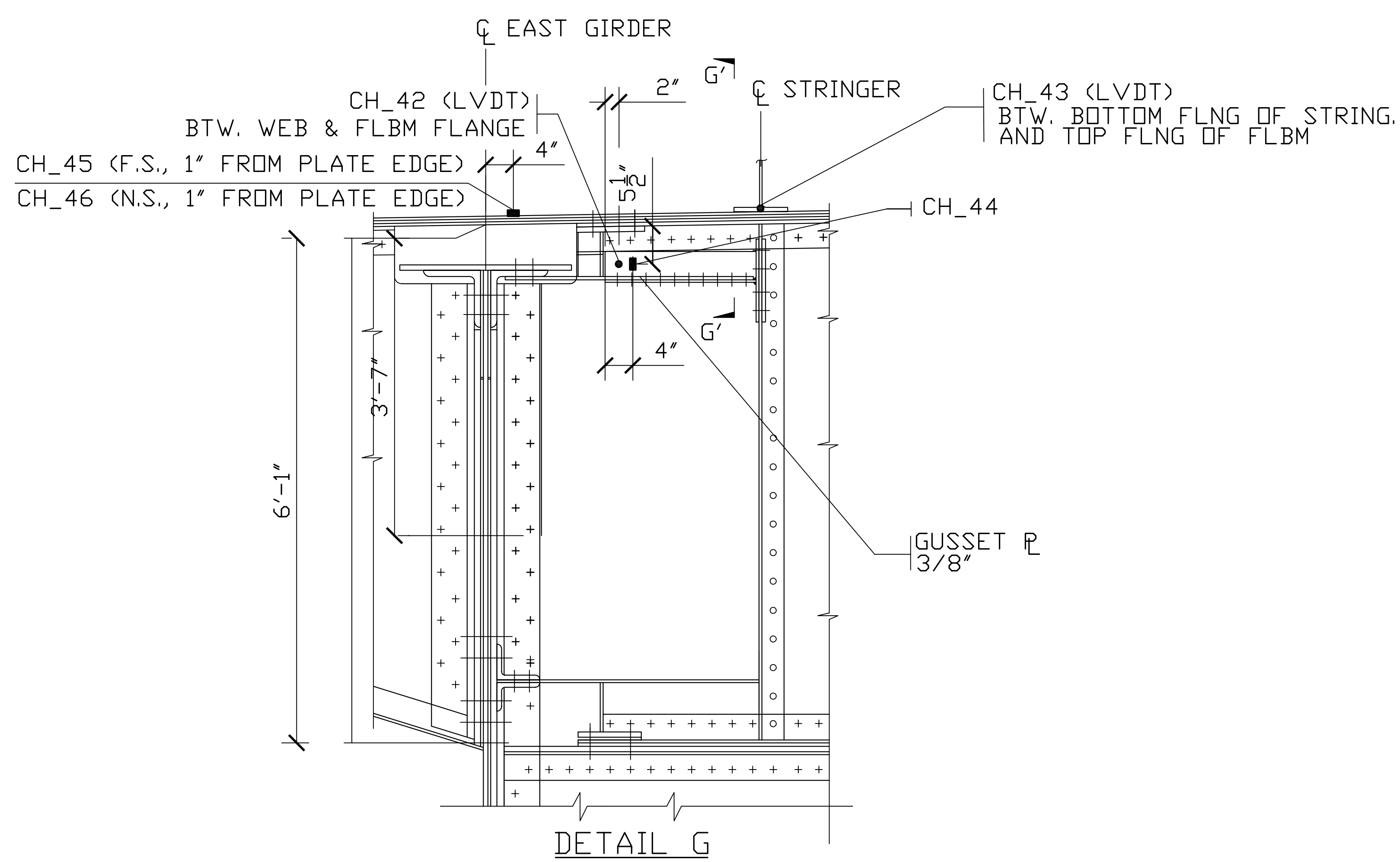
SHEET TITLE

SHEET NO.:

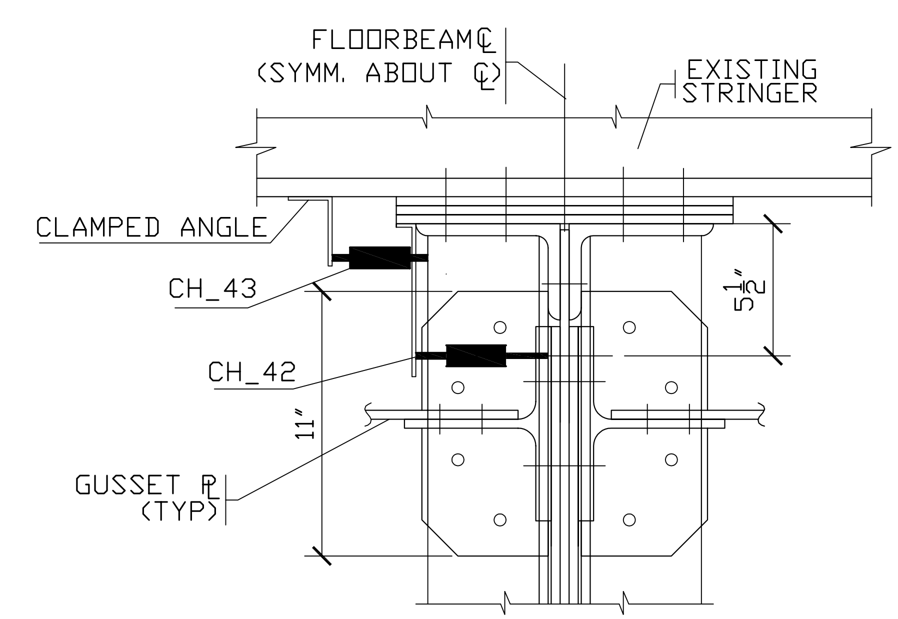
3 OF 6



SECTION F-F: FLOORBEAM NO. 2
VIEW LOOKING NORTH
SCALE: 1/8"=1'-0"



DETAIL G
LOOKING SOUTH
SCALE: 1/2"=1'-0"



SECTION: G'-G'
LOOKING EAST
SCALE: 1 1/2"=1'-0"

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PROJECT:

THROGS NECK OVER THE EAST RIVER NEW YORK, NY

SHEET NOTES:

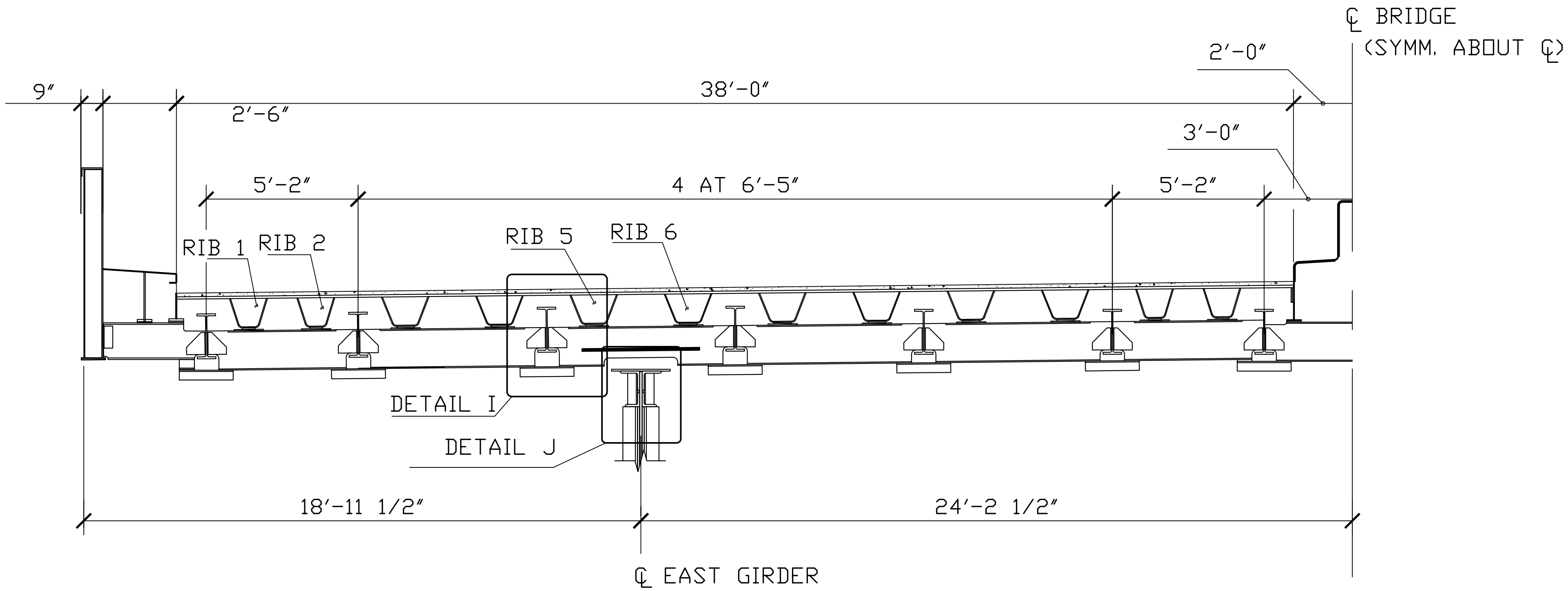
SPAN 38

NO.	DESCRIPTION	DATE	BY
1	INITIAL SUBMITTAL	?/?/??	

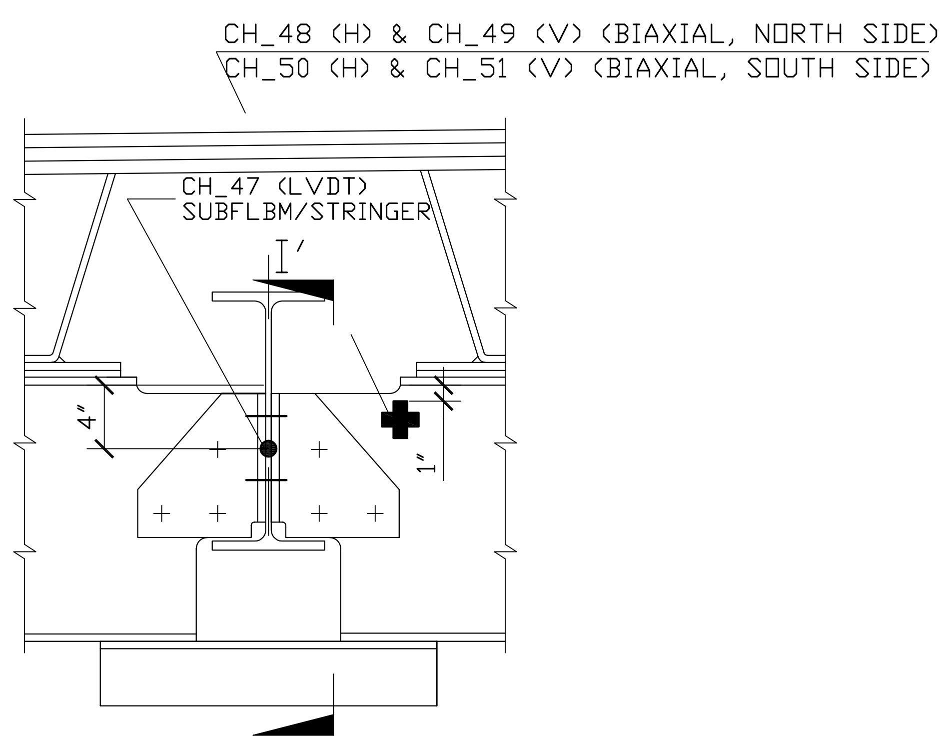
DESIGNED BY:	RJC & HNM
DRAWN BY:	HNM
CHECKED BY:	RJC
SCALE:	VARIES
DATE:	5/12/05
PROJECT NO.:	526701
SHEET TITLE:	

SHEET TITLE

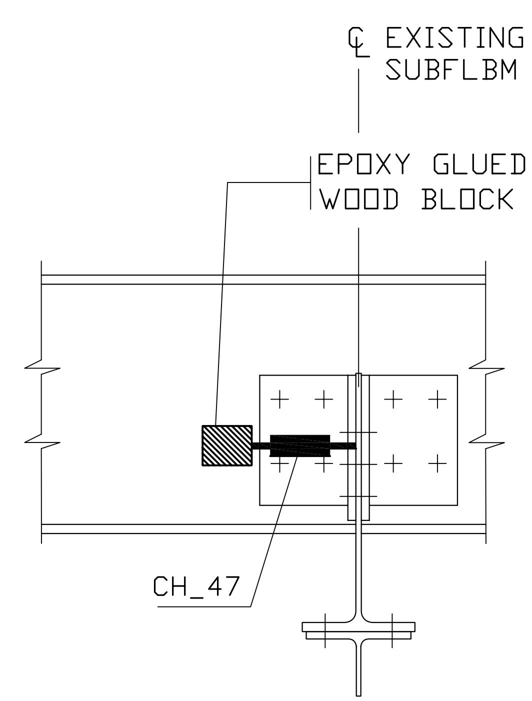
SHEET NO.:



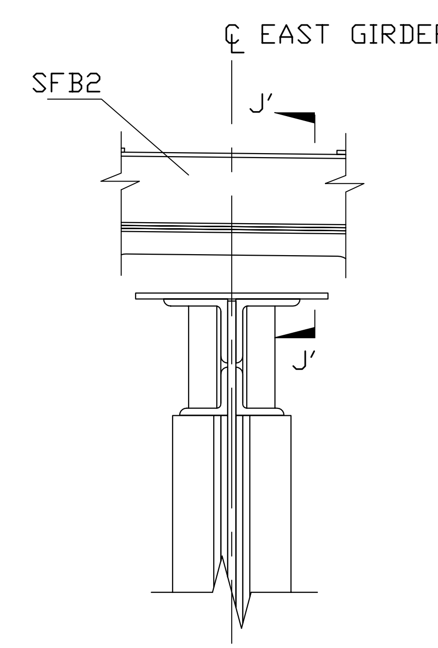
SECTION H-H: AT INTERMEDIATE SUBFLOORBEAM 2
LOOKING SOUTH
SCALE: 3/16"=1'-0"



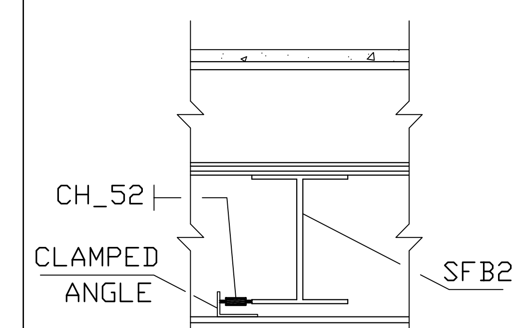
DETAIL I
LOOKING NORTH
SCALE: 1"=1'-0"



SECTION: I'-I'
LOOKING EAST
SCALE: 1"=1'-0"



DETAIL J
LOOKING SOUTH
SCALE: 1/2"=1'-0"



SECTION J'-J'
LOOKING EAST
SCALE: 1/2"=1'-0"

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PROJECT:

THROGS NECK OVER THE EAST RIVER NEW YORK, NY

SHEET NOTES:

SPAN 38

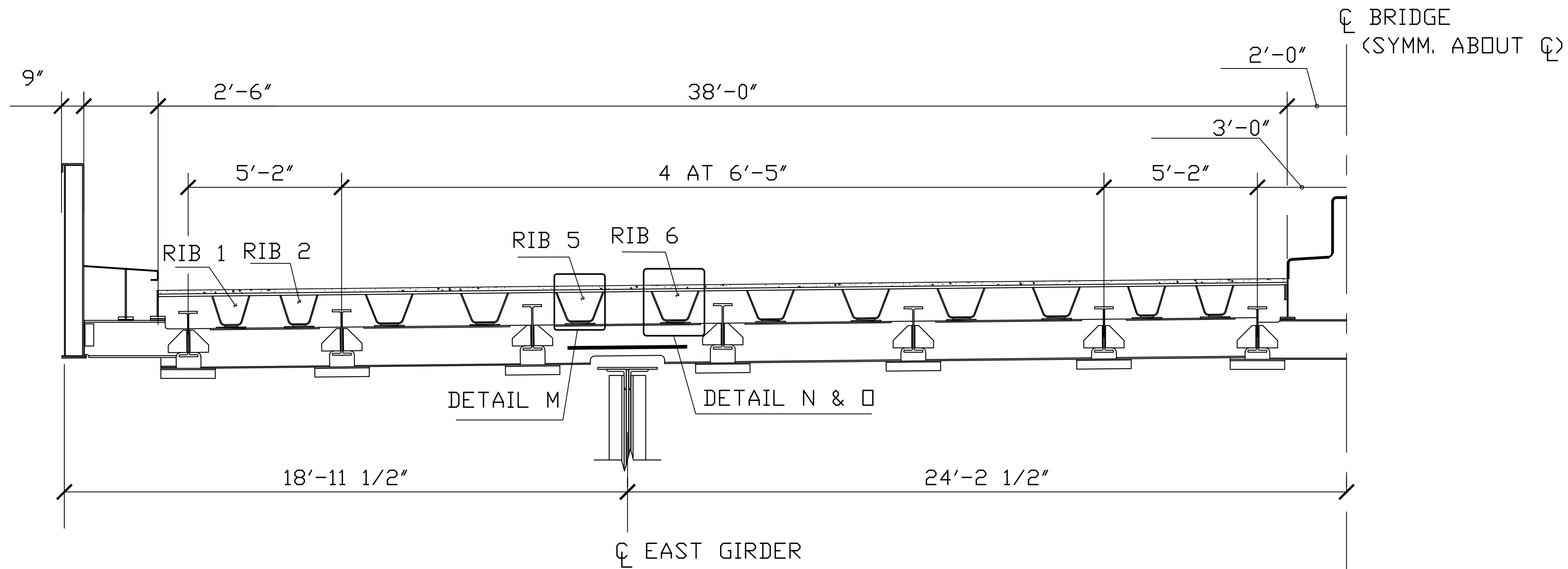
NO.	DESCRIPTION	DATE	BY
1	INITIAL SUBMITTAL	??/??/??	

DESIGNED BY:	RJC & HNM
DRAWN BY:	HNM
CHECKED BY:	RJC
SCALE:	VARIES
DATE:	5/12/05
PROJECT NO.:	526701
SHEET TITLE:	

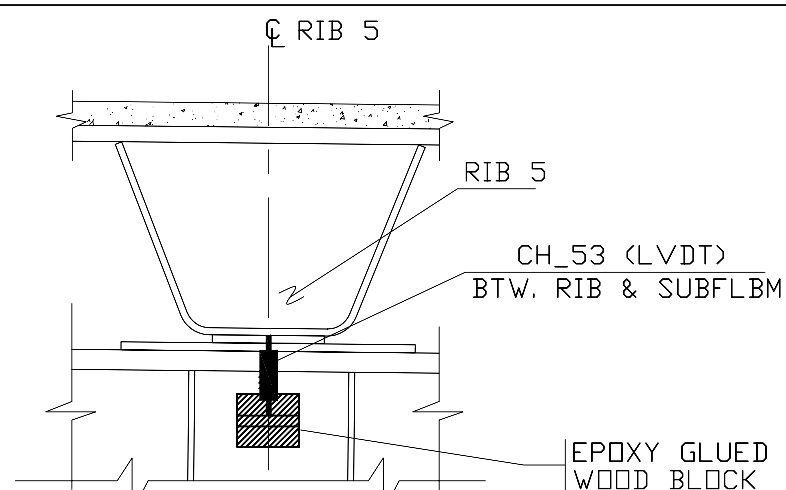
SHEET TITLE

SHEET NO.:

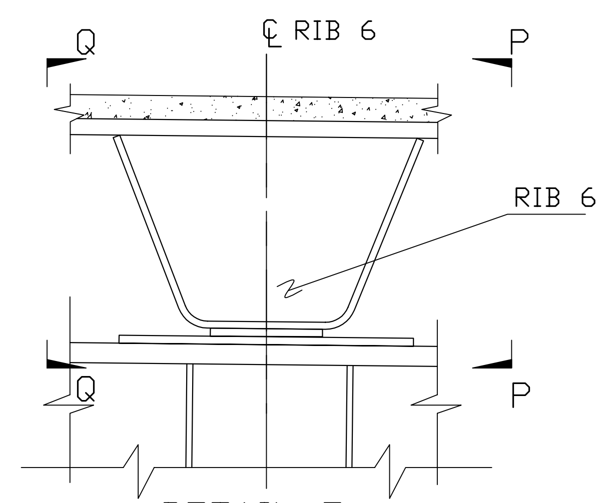
5 OF 6



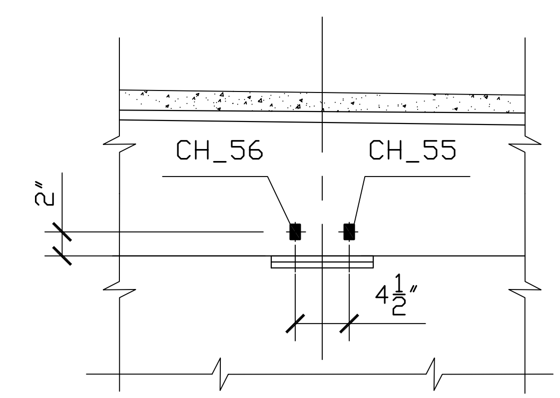
SECTION H-H: AT SUBFLOORBEAM 2
LOOKING SOUTH
SCALE: 3/16"=1'-0"



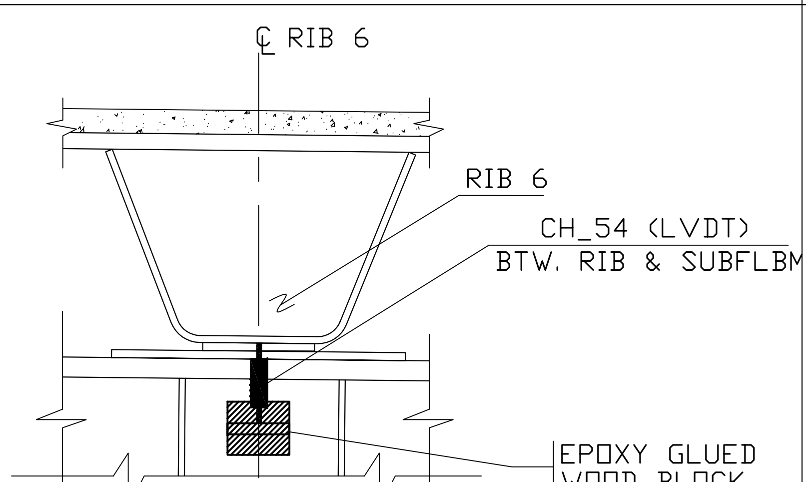
DETAIL M
LOOKING SOUTH
SCALE: 1"=1'-0"



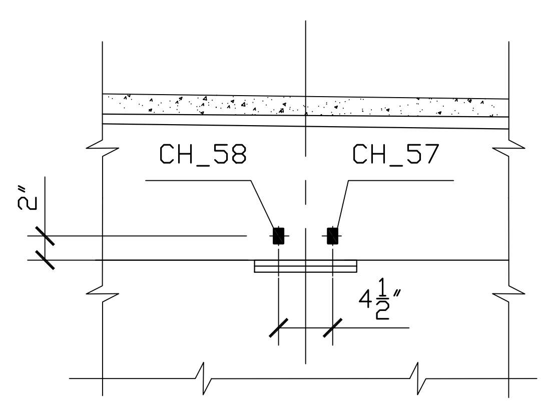
DETAIL O
LOOKING SOUTH
SCALE: 1"=1'-0"



SECTION P-P (WITHOUT BACKING PLATE)
LOOKING EAST
SCALE: 3/4"=1'-0"



DETAIL N
LOOKING SOUTH
SCALE: 1"=1'-0"



SECTION Q-Q (WITHOUT BACKING PLATE)
LOOKING WEST
SCALE: 3/4"=1'-0"

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PROJECT:

THROGS NECK OVER THE EAST RIVER
NEW YORK, NY

SHEET NOTES:

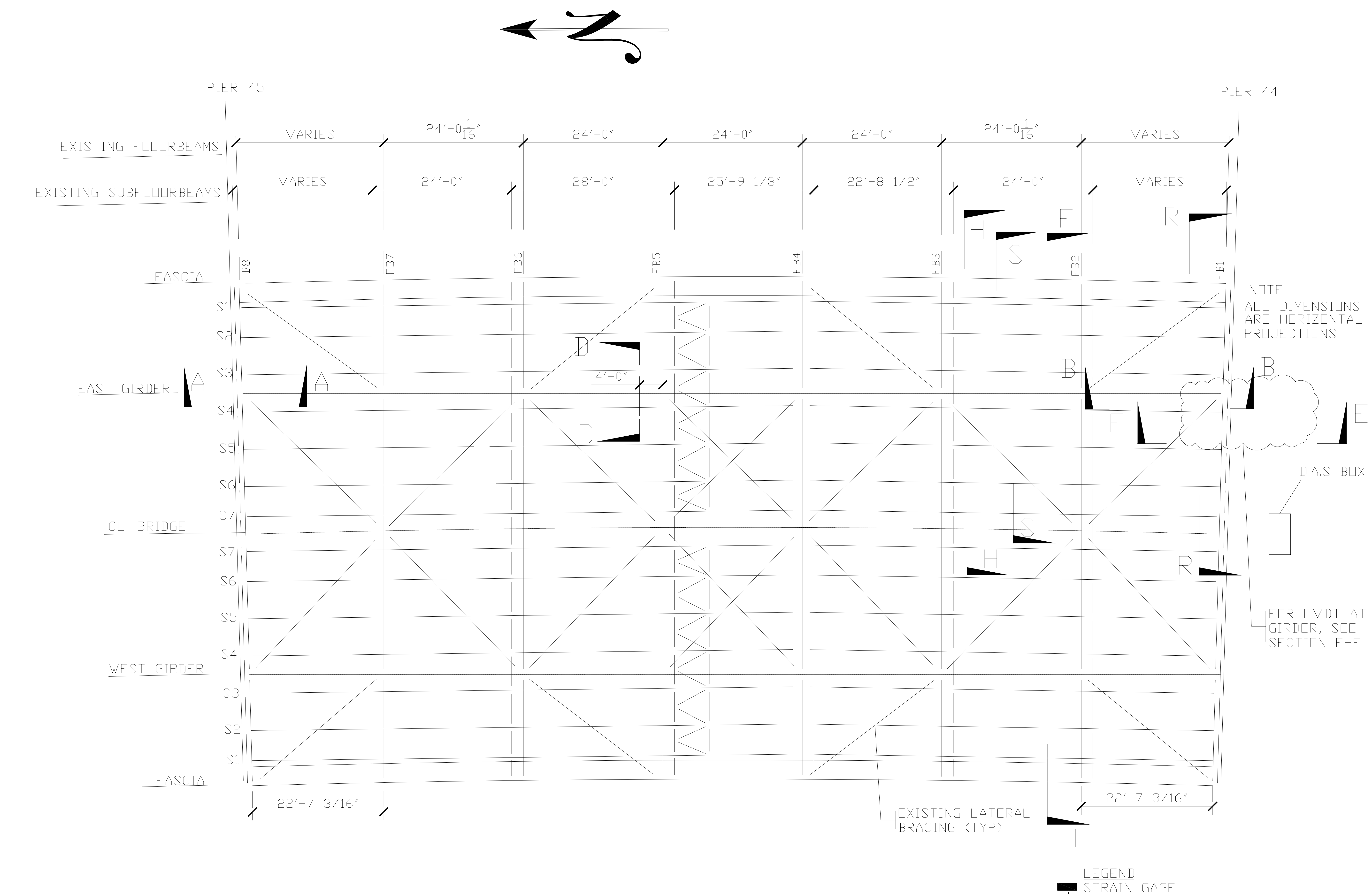
SPAN 38

NO.	DESCRIPTION	DATE	BY
1	INITIAL SUBMITTAL	?/?/??	

DESIGNED BY:	RJC & HNM
DRAWN BY:	HNM
CHECKED BY:	RJC
SCALE:	VARIES
DATE:	5/12/05
PROJECT NO.:	526701
SHEET TITLE:	

SHEET TITLE

SHEET NO.:



CHANNEL PLAN LAYOUT (SPAN 45)

SCALE: 1/16"=1'-0"

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PROJECT:

THROGS NECK OVER THE EAST RIVER NEW YORK, NY

SHEET NOTES:

SPAN 45

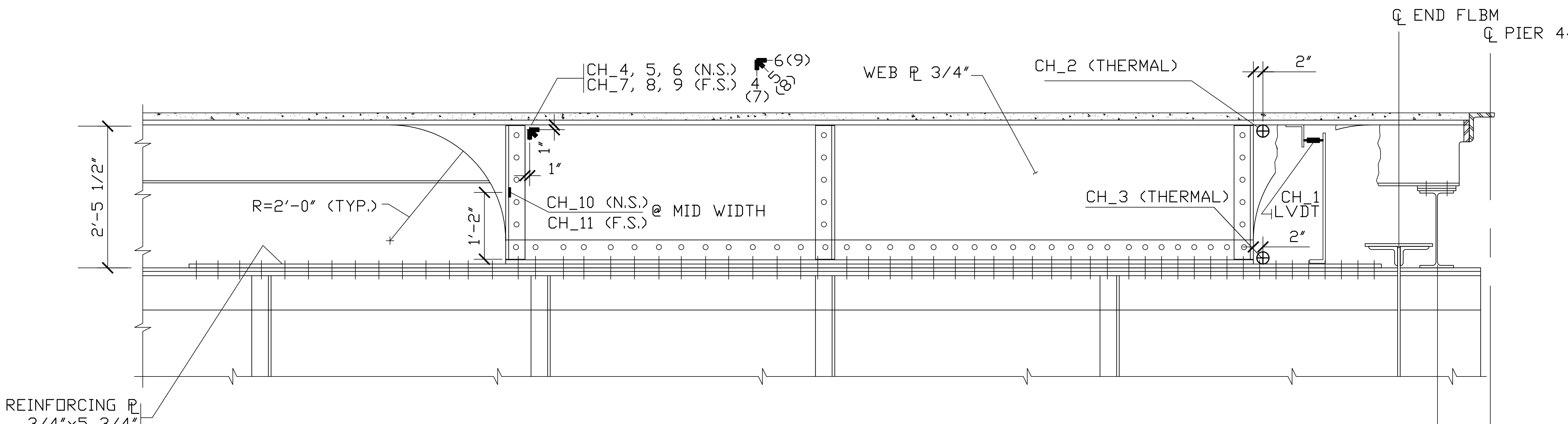
NO.	DESCRIPTION	DATE	BY
1	INITIAL SUBMITTAL	??/??	HNM

DESIGNED BY:	RJC & HNM
DRAWN BY:	HNM
CHECKED BY:	RJC
SCALE:	1/16" = 1'-0"
DATE:	5/12/05
PROJECT NO.:	526701
SHEET TITLE:	

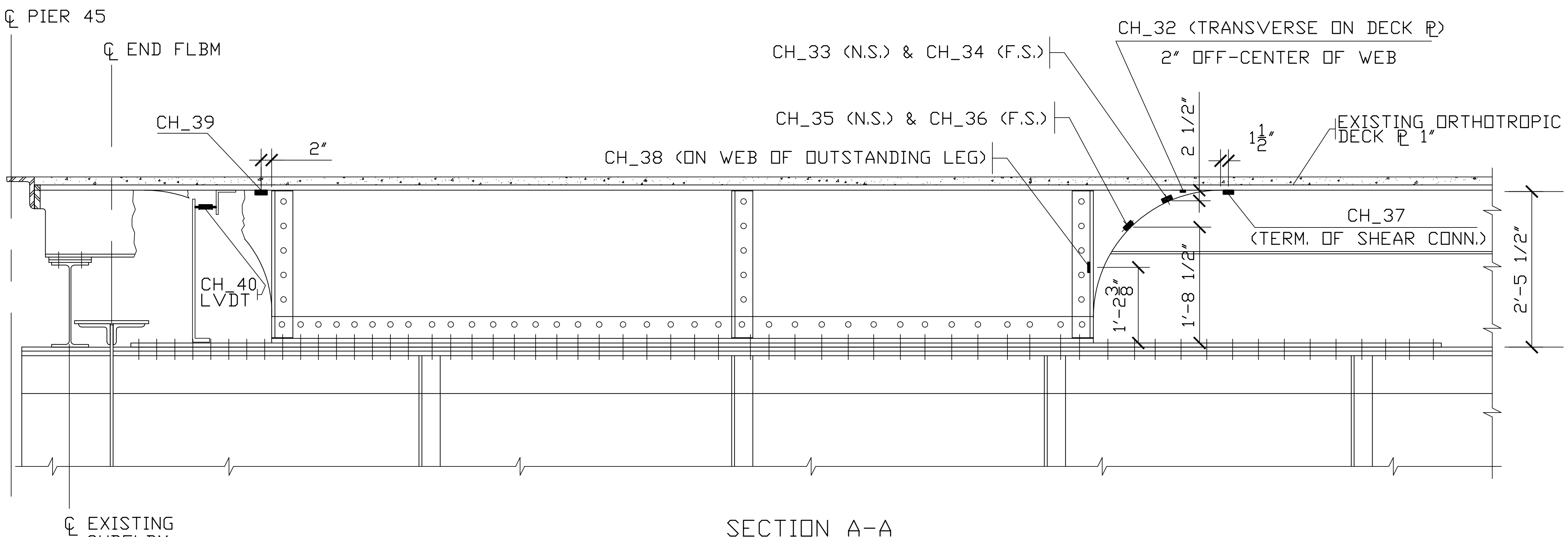
SHEET TITLE

SHEET NO.:

1 OF 8



SECTION B-B
LOOKING EAST
SCALE: 1/2"=1'-0"



SECTION A-A
LOOKING EAST
SCALE: 1/2"=1'-0"

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PROJECT:

THROGS NECK OVER THE EAST RIVER NEW YORK, NY

SHEET NOTES:

SPAN 45

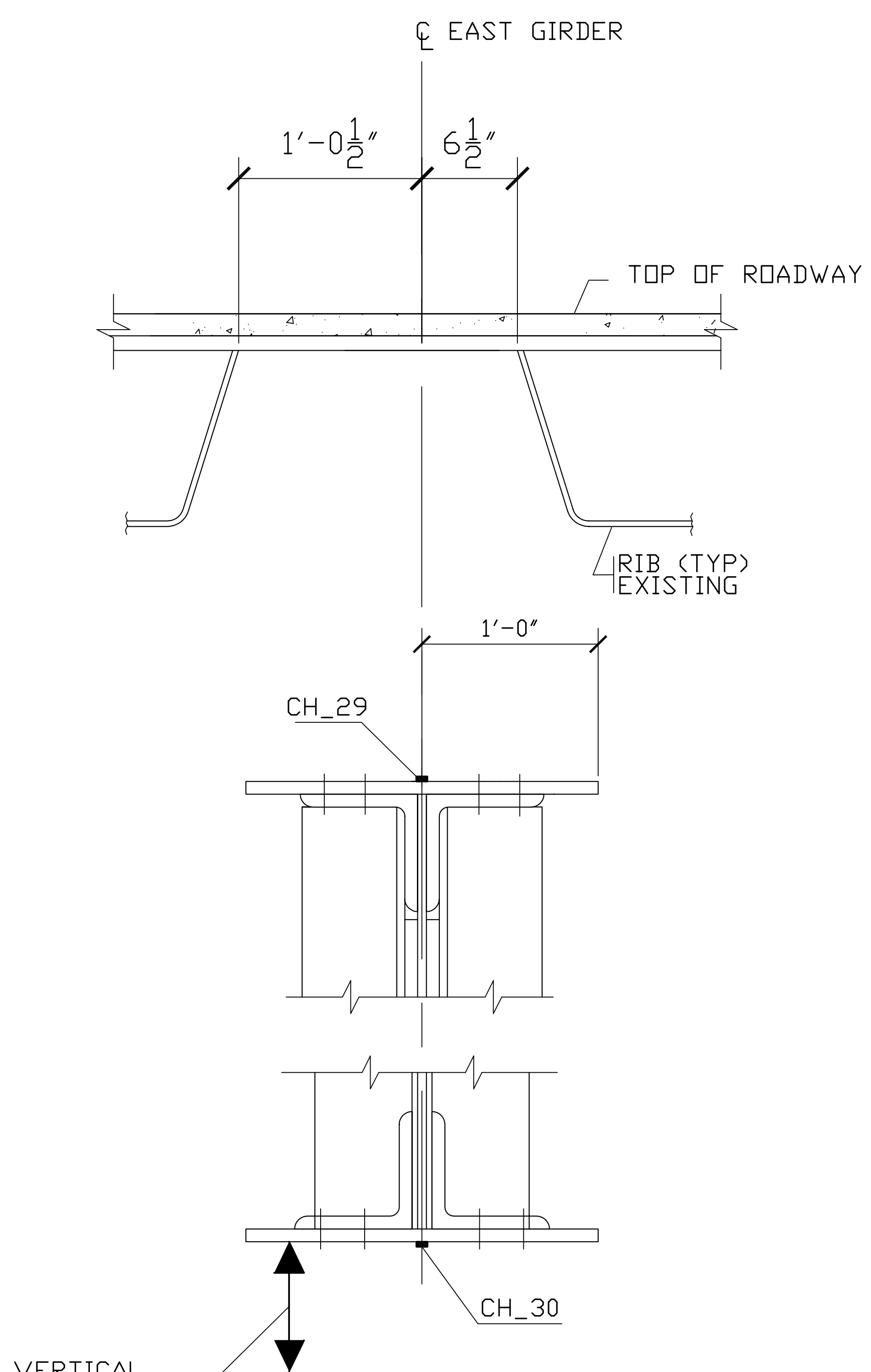
NO.	DESCRIPTION	DATE	BY
1	INITIAL SUBMITTAL	??/??/??	

DESIGNED BY:	RJC & HNM
DRAWN BY:	HNM
CHECKED BY:	RJC
SCALE:	1/8" = 1'-0"
DATE:	5/12/05
PROJECT NO.:	526701
SHEET TITLE:	

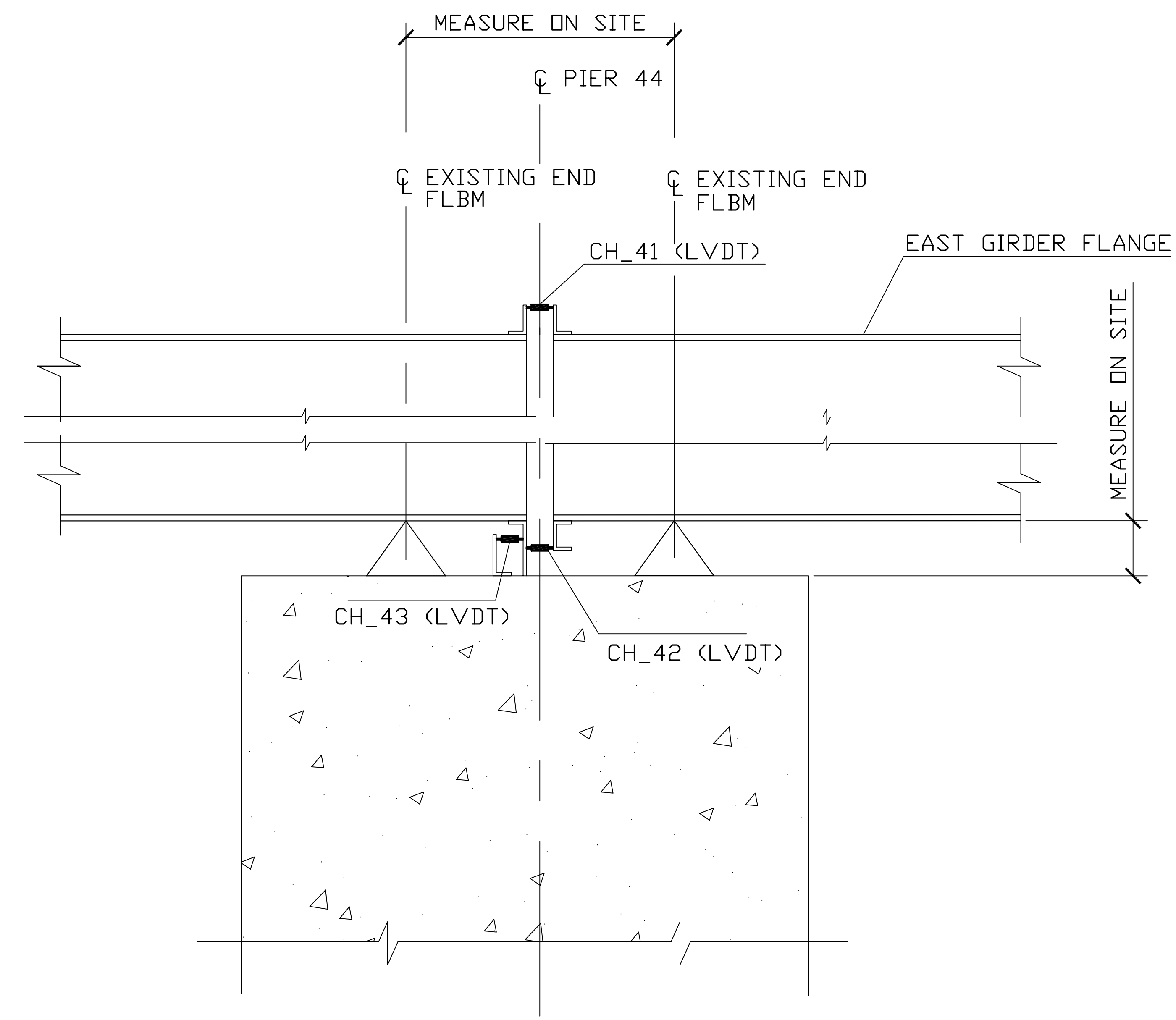
SHEET TITLE

SHEET NO.:

2 OF 8



SECTION D-D
LOOKING NORTH
SCALE: 3/4"=1'-0"



SECTION E-E
LOOKING EAST
SCALE: N.T.S

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PROJECT:
THROGS NECK OVER THE EAST RIVER NEW YORK, NY

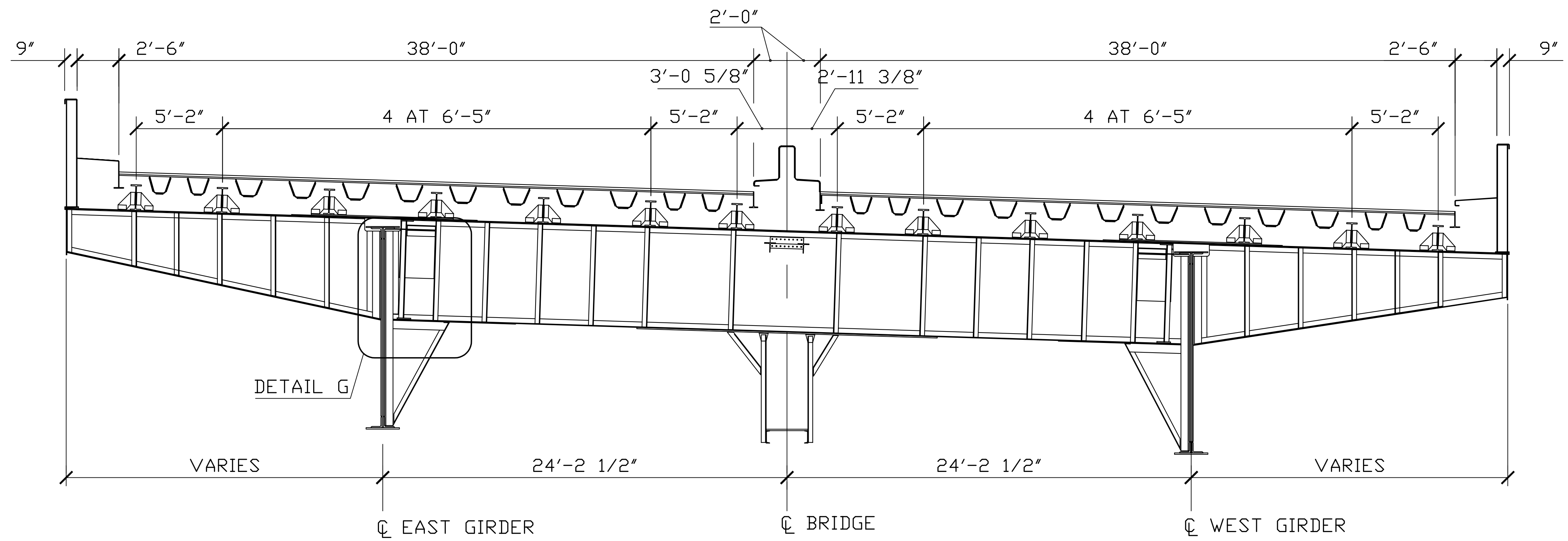
SHEET NOTES:
SPAN 45

NO.	DESCRIPTION	DATE	BY
1	INITIAL SUBMITTAL	?/?/??	

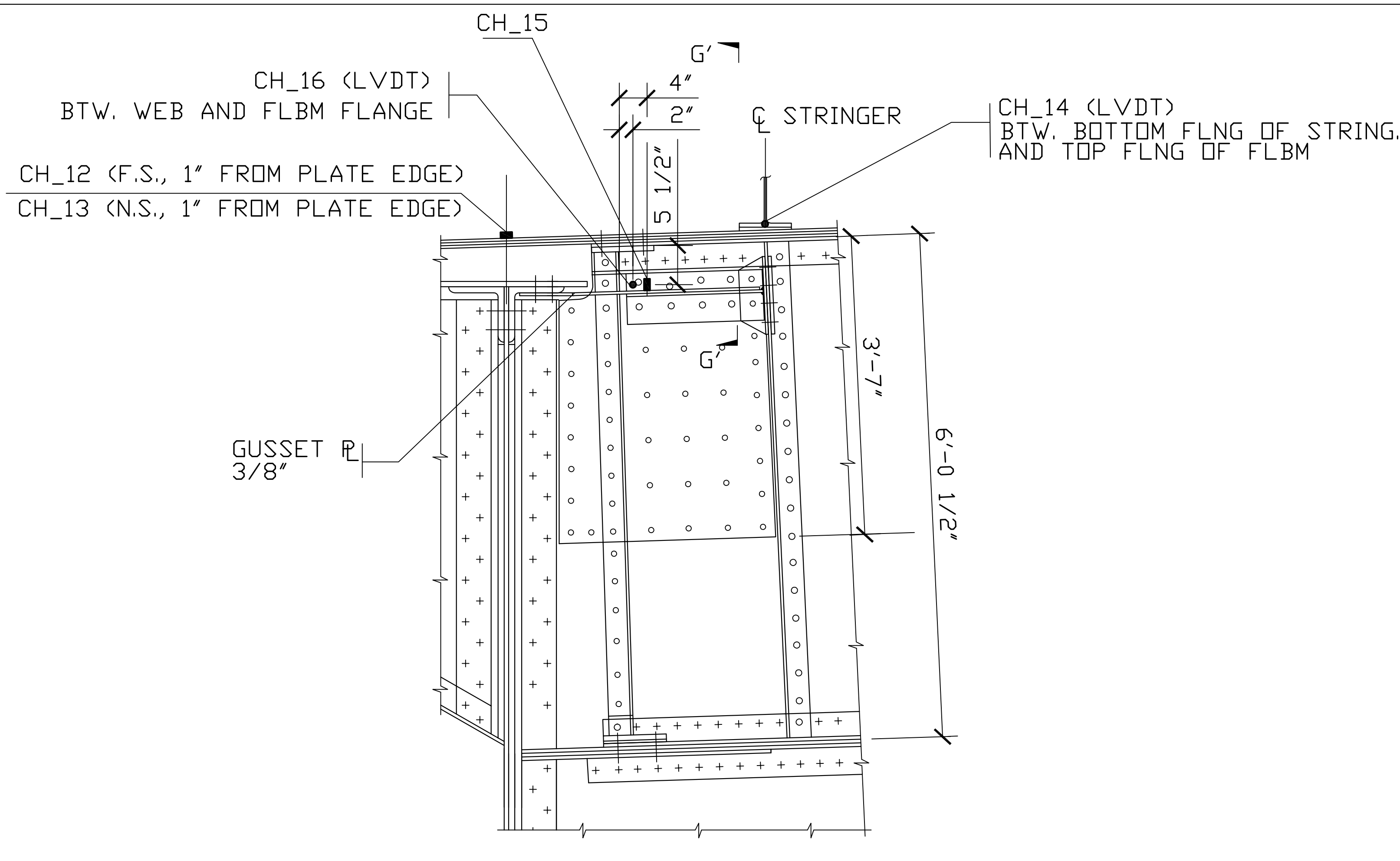
DESIGNED BY:	RJC & HNM
DRAWN BY:	HNM
CHECKED BY:	RJC
SCALE:	1/8" = 1'-0"
DATE:	5/12/05
PROJECT NO.:	526701
SHEET TITLE:	

SHEET TITLE

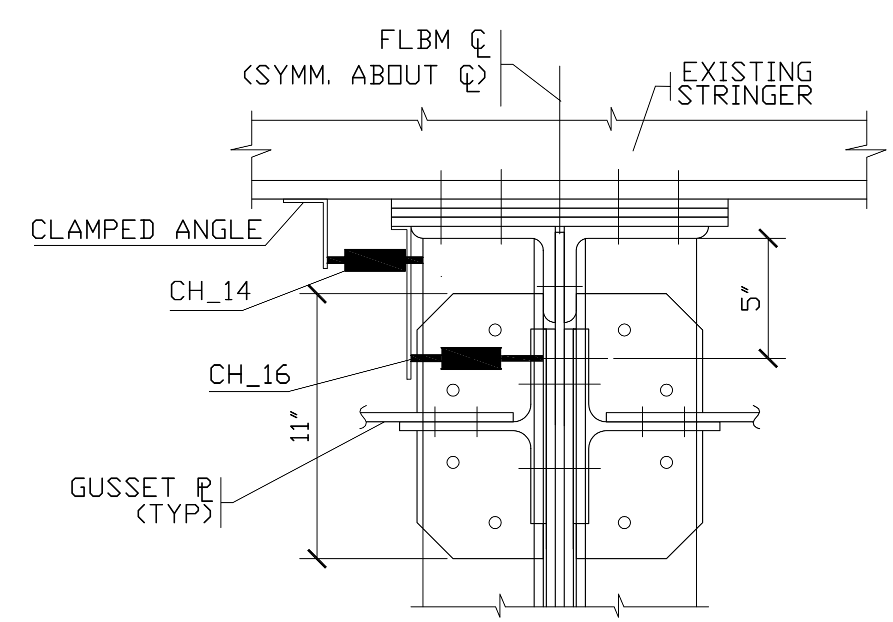
SHEET NO.:



SECTION F-F: FLOORBEAM NO. 2
LOOKING SOUTH
SCALE: 1/8″=1′-0″



DETAIL G
LOOKING SOUTH
SCALE: 1/2″=1′-0″



SECTION: G′-G′
LOOKING EAST
SCALE: 1 1/2″=1′-0″

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THROGS NECK OVER THE EAST RIVER NEW YORK, NY

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SPAN 45

NO.	DESCRIPTION	DATE	BY
1	INITIAL SUBMITTAL	?/?/??	

DESIGNED BY:	RJC & HNM
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CHECKED BY:	RJC
SCALE:	1/8″ = 1′-0″
DATE:	5/12/05
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SHEET TITLE:	

SHEET TITLE

SHEET NO.:

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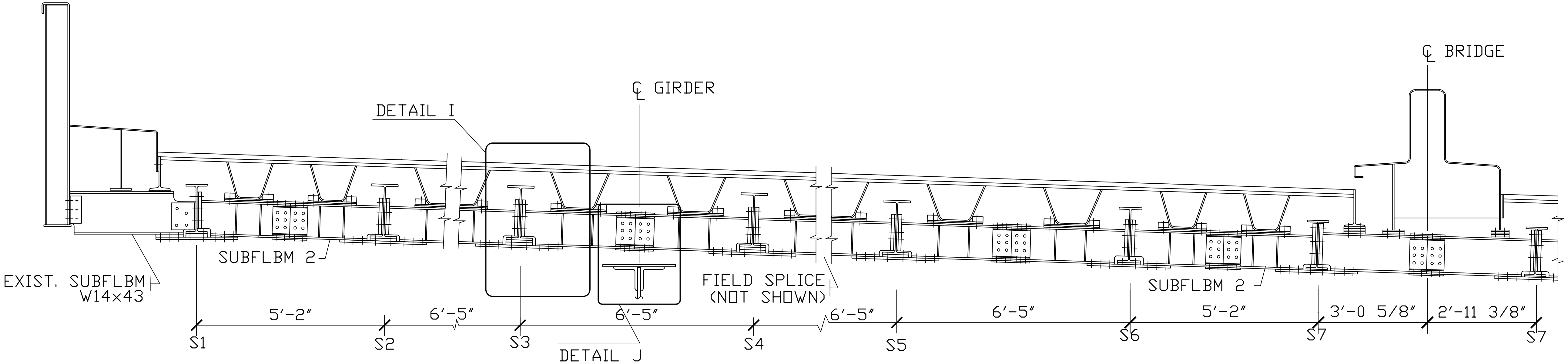
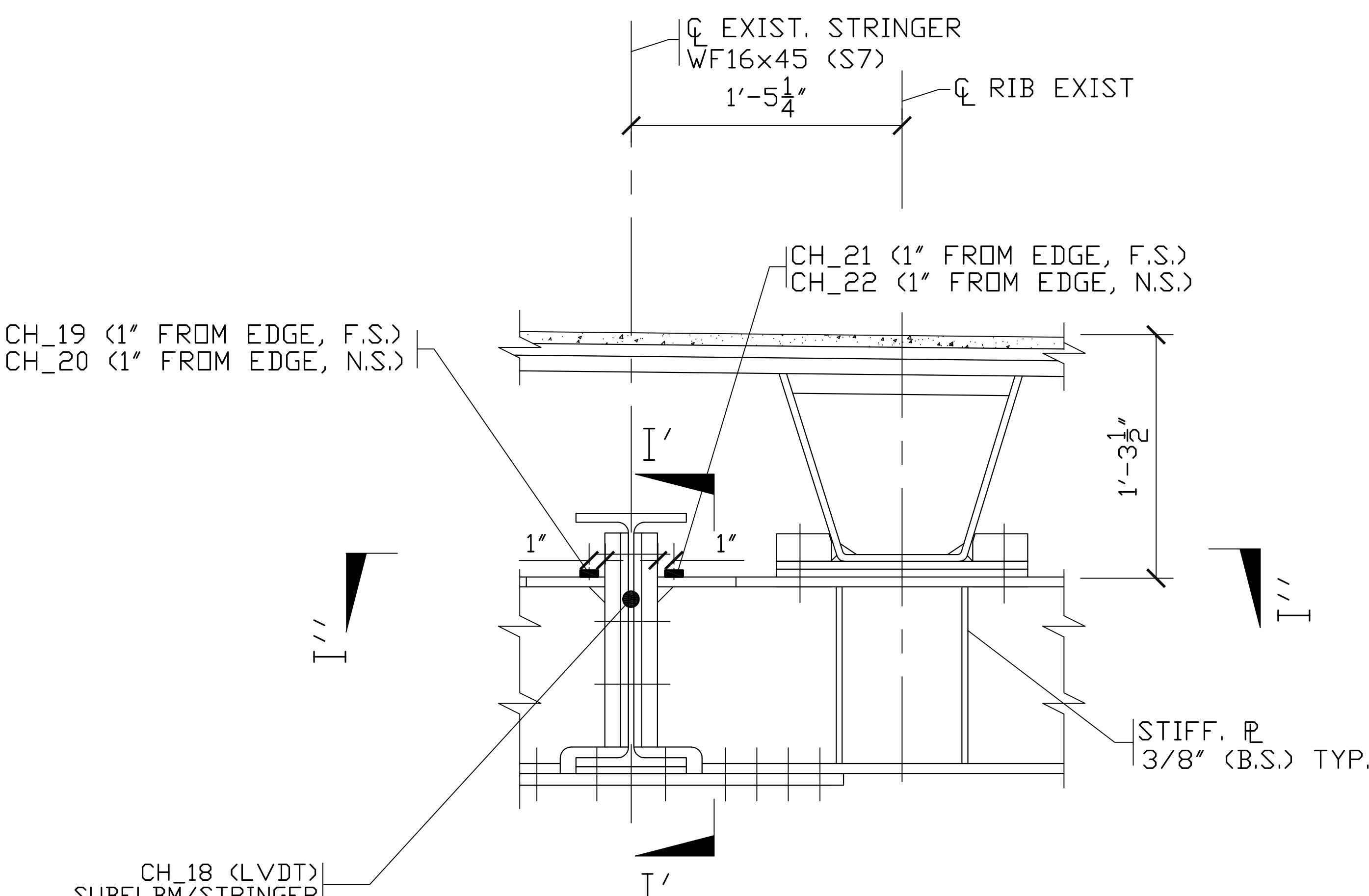
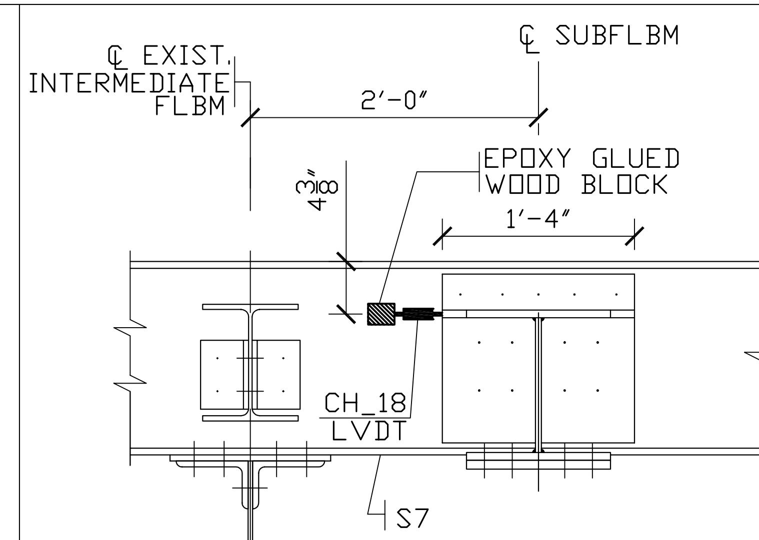


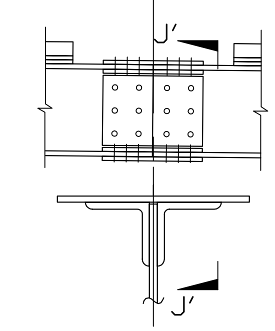
SECTION H-H: AT INTERMEDIATE SUBFLOORBEAM 2
LOOKING SOUTH
SCALE: 5/16"=1'-0"



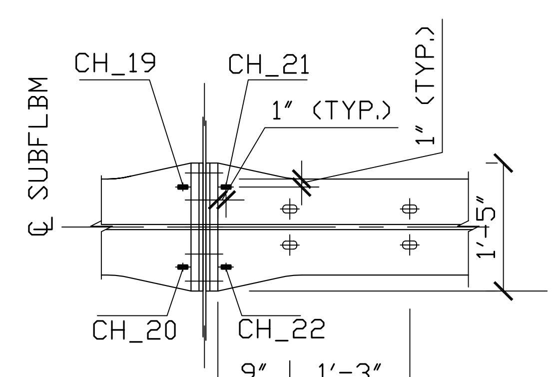
DETAIL I
LOOKING SOUTH
SCALE: 1"=1'-0"



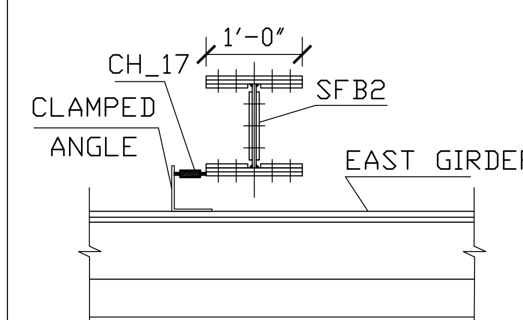
SECTION: I'-I'
LOOKING EAST
SCALE: 3/4"=1'-0"



DETAIL J
LOOKING SOUTH
SCALE: 1/2"=1'-0"



SECTION I''-I''
PLAN VIEW
SCALE: 1/2"=1'-0"



SECTION J'-J'
LOOKING EAST
SCALE: 1/2"=1'-0"

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PROJECT:

THROGS NECK OVER THE EAST RIVER NEW YORK, NY

SHEET NOTES:

SPAN 45

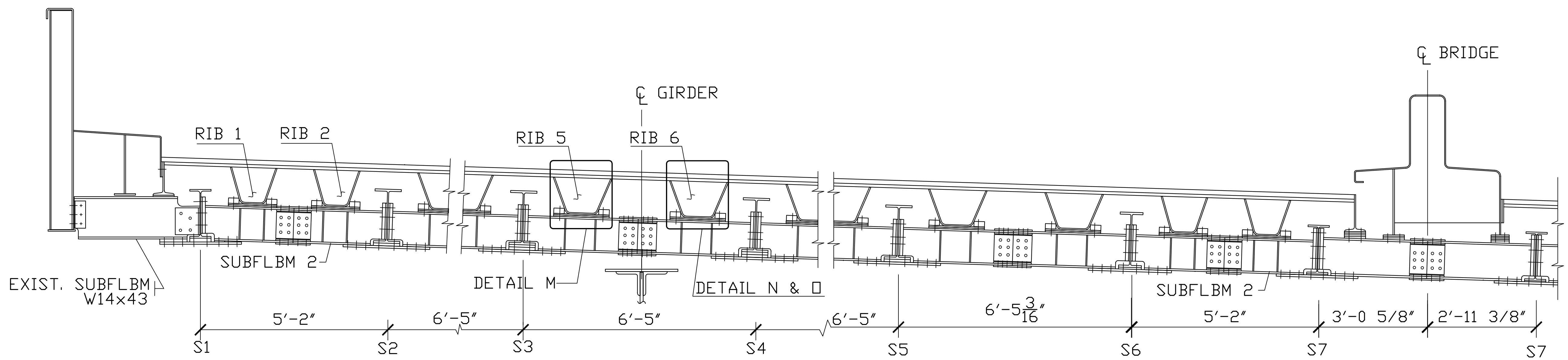
NO.	DESCRIPTION	DATE	BY
1	INITIAL SUBMITTAL	?/?/??	

DESIGNED BY:	RJC & HNM
DRAWN BY:	HNM
CHECKED BY:	RJC
SCALE:	VARIES
DATE:	5/12/05
PROJECT NO.:	526701
SHEET TITLE:	

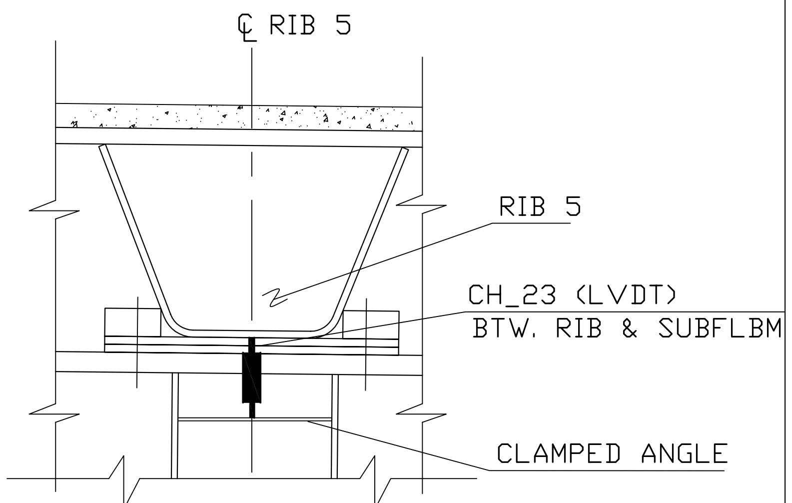
SHEET TITLE

SHEET NO.:

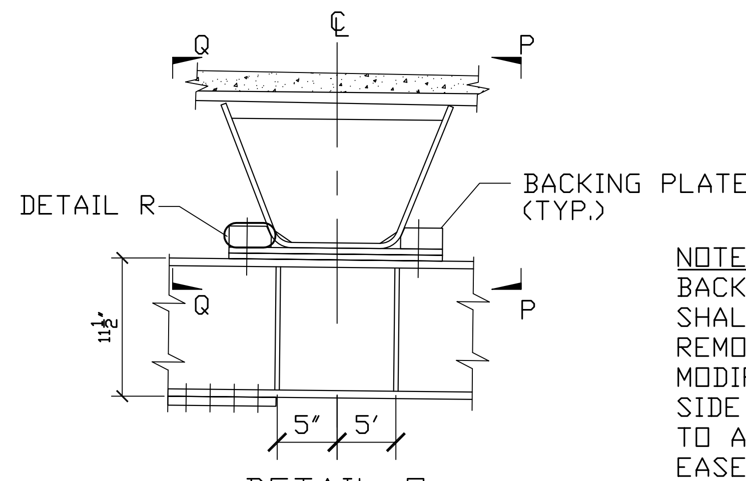
5 OF 8



SECTION H-H: AT INTERMEDIATE SUBFLOORBEAM 2
LOOKING SOUTH
SCALE: 5/16"=1'-0"

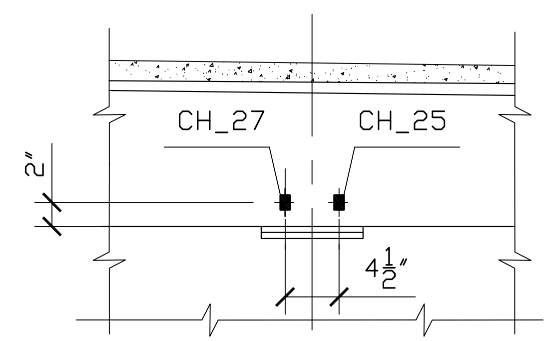


DETAIL M
LOOKING SOUTH
SCALE: 1"=1'-0"

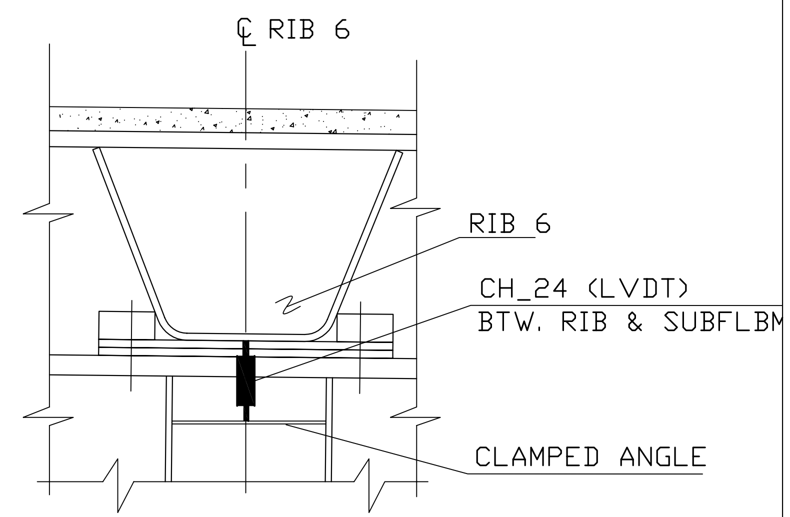


DETAIL O
LOOKING SOUTH
SCALE: 3/4"=1'-0"

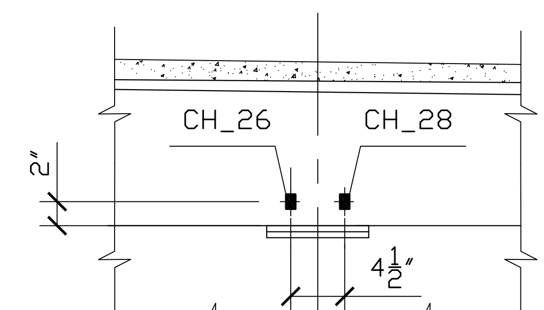
NOTE:
BACKING PLATES SHALL BE REMOVED AND MODIFIED ON EACH SIDE OF THE RIB TO ALLOW FOR EASE OF GAGE INSTALLATION AND WIRE PLACEMENT (SEE DETAIL R)



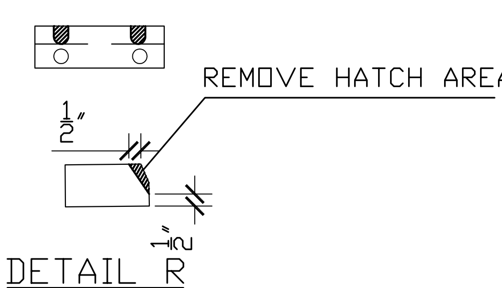
SECTION P-P
LOOKING EAST
SCALE: 3/4"=1'-0"



DETAIL N
LOOKING SOUTH
SCALE: 1"=1'-0"



SECTION Q-Q
LOOKING WEST
SCALE: 3/4"=1'-0"



DETAIL R

SCALE: 1 1/2"=1'-0"

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SHEET NOTES:

SPAN 45

NO.	DESCRIPTION	DATE	BY
1	INITIAL SUBMITTAL	??/??/??	

DESIGNED BY:	RJC & HNM
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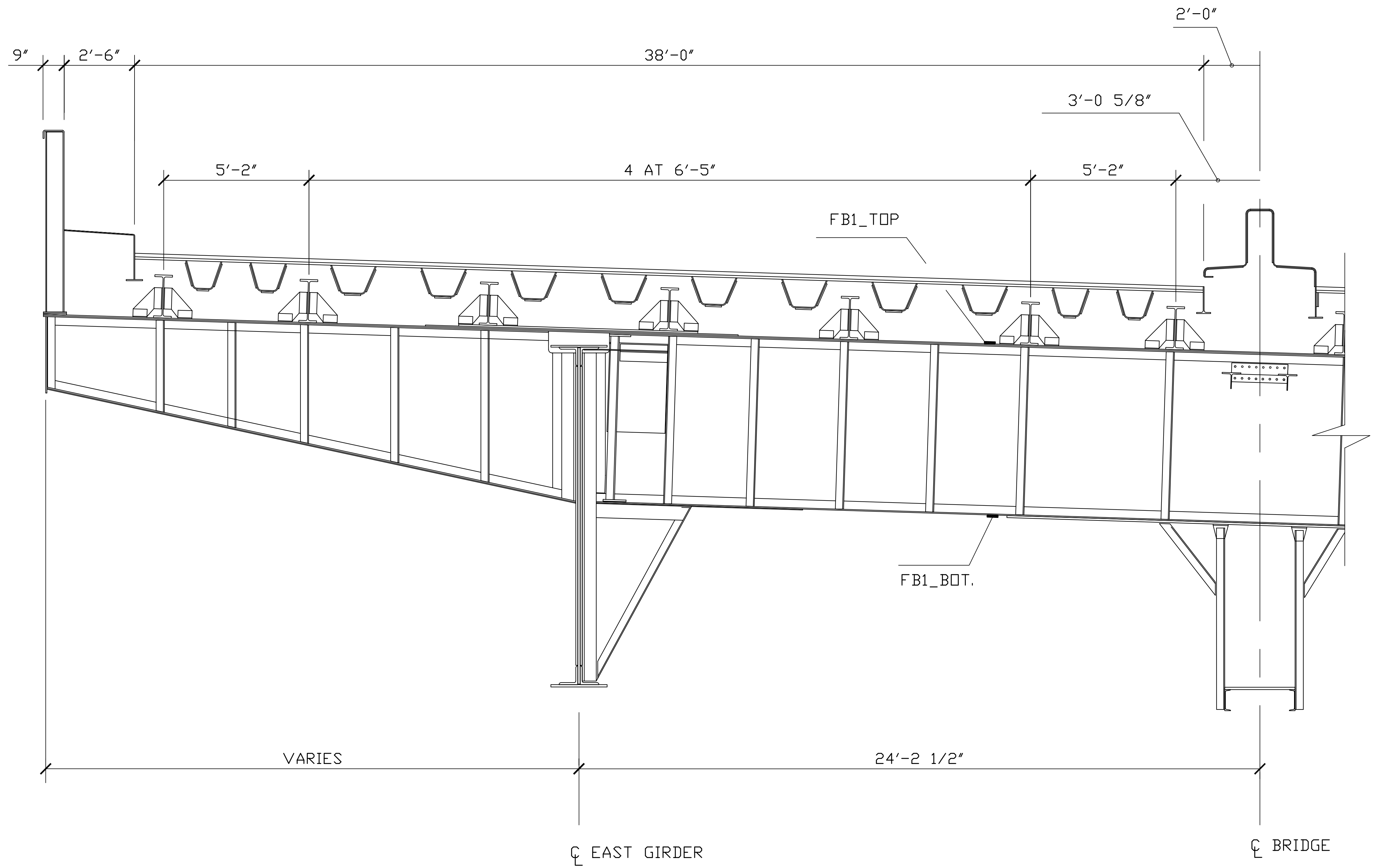
CHECKED BY:	RJC
SCALE:	VARIES
DATE:	5/12/05
PROJECT NO.:	526701
SHEET TITLE:	

SHEET TITLE

SHEET NO.:



SECTION R-R: FLOORBEAM NO. 1
LOOKING SOUTH
SCALE: 1/4"=1'-0"

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THROGS NECK OVER THE EAST RIVER NEW YORK, NY

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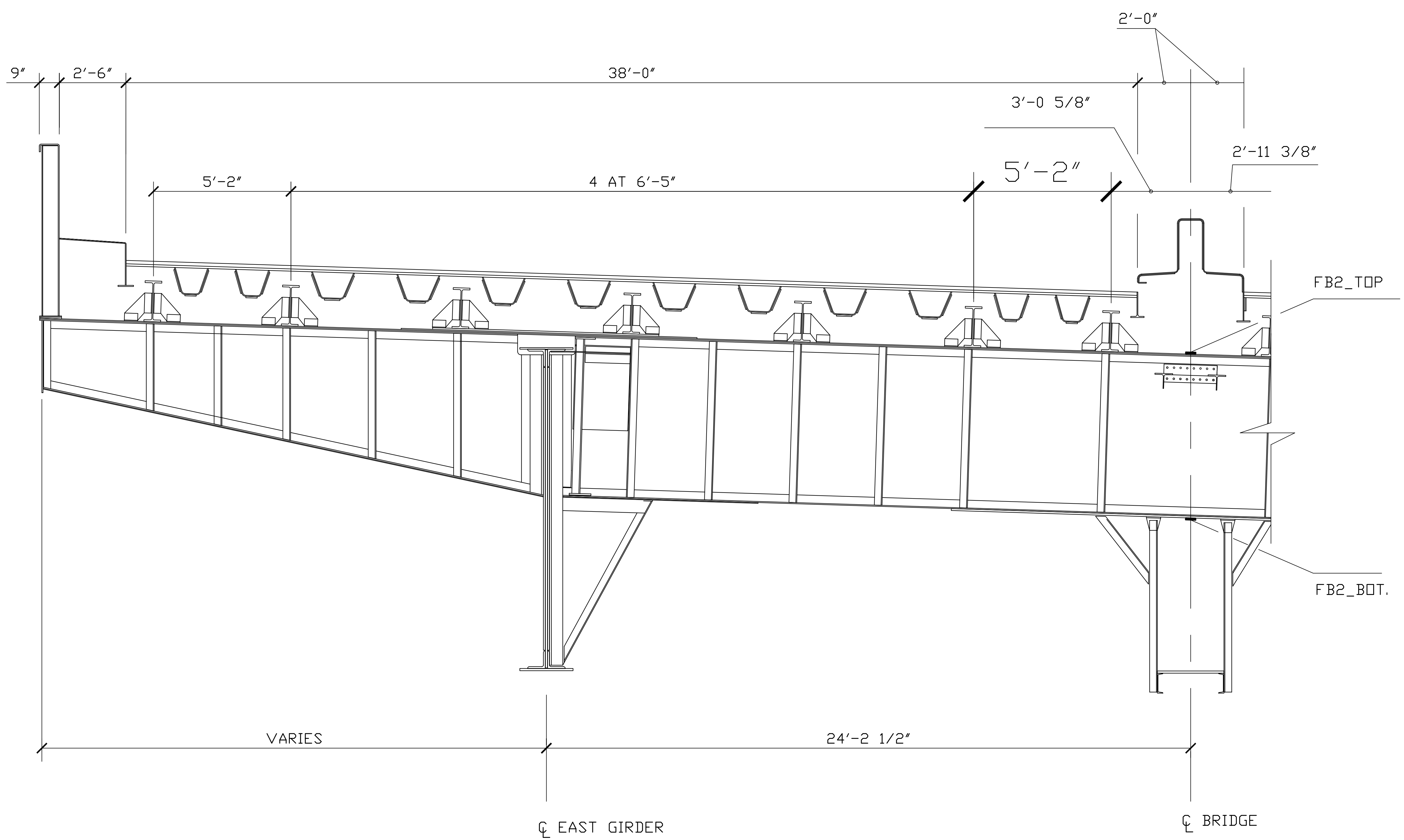
SPAN 45

NO.	DESCRIPTION	DATE	BY
1	INITIAL SUBMITTAL	?/?/??	

DESIGNED BY:	JWF & HNM
DRAWN BY:	HNM
CHECKED BY:	JWF
SCALE:	1/8" = 1'-0"
DATE:	10/06/05
PROJECT NO.:	526701
SHEET TITLE:	

SHEET TITLE

SHEET NO.:



SECTION S-S: FLOORBEAM NO. 2
LOOKING SOUTH
SCALE: 1/4"=1'-0"

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THROGS NECK OVER THE EAST RIVER NEW YORK, NY

SHEET NOTES:

SPAN 45

NO.	DESCRIPTION	DATE	BY
1	INITIAL SUBMITTAL	?/?/??	

DESIGNED BY:	JWF & HNM
DRAWN BY:	HNM
CHECKED BY:	JWF
SCALE:	1/8" = 1'-0"
DATE:	10/06/05
PROJECT NO.:	526701
SHEET TITLE:	

SHEET TITLE

SHEET NO.:

Appendix B

Development of Stress-Range Histograms used to Calculate Fatigue Damage

Stress-Range Histograms

The stress-range histogram data collected during the uncontrolled monitoring permitted the development of a random variable-amplitude stress-range spectrum for the selected strain gages. It has been shown that a variable-amplitude stress-range spectrum can be represented by an equivalent constant-amplitude stress range equal to the cube root of the mean cube (rmc) of all stress ranges (i.e., Miner's rule) [1] (i.e., $S_{reff} = [\Sigma\alpha_i S_{ri}^3]^{1/3}$).

During the long-term monitoring program, stress-range histograms were developed using the rainflow cycle counting method [2]. Although several other methods have been developed to convert a random-amplitude stress-range response into a stress-range histogram, the rainflow cycle counting method is widely used and accepted for use in most structures. During the long-term monitoring program, the rainflow analysis algorithm was programmed to ignore any stress range less than 0.50 ksi (18με). Hence, the "raw" histograms do not include these very small cycles. Such small cycles do not contribute to the overall fatigue damage of even the worst details and if included, can actually unconservatively skew the results, as will be discussed below. It is also worth mentioning, that in some testing environments, the validity of stress-range cycles less than this are often questionable due to electromechanical noise.

The effective stress range presented for each channel in the body of the report was calculated by ignoring all stress-range cycles obtained from the stress-range histograms that were less than predetermined limits. (*It should be noted that the limit described here should not be confused with the limit described above. The limit above (i.e., 0.50 ksi (18με)) refers to the threshold of the smallest amplitude cycle that was counted by the algorithm and not related to the cycles that were counted, but later ignored, to ensure an accurate fatigue life estimate, as will be discussed.*) For all welded steel details, a cut-off or threshold is appropriate and necessary, as will be discussed. The limits were typically about ¼ the constant amplitude fatigue limit for the respective detail. For example, for strain gages installed at details that are characterized as category C, with a CAFL of 10.0 ksi, the cutoff was set at 2.5 ksi. Hence, stress range cycles less than 2.5 ksi were ignored in the preparation of the stress-range histograms used to calculate the effective stress range and the number of cycles accumulated. The threshold was selected for two reasons.

Previous research has demonstrated that stress ranges less than about ¼ the CAFL have little effect on the cumulative damage at the detail [3]. It has also been demonstrated that as the number of random variable cycles of lower stress range levels are considered, the predicted cumulative damage provided by the calculated effective stress range becomes asymptotic to the applicable S-N curve. A similar approach of truncating cycles of low stress range is accepted by researchers and specifications throughout the world [4].

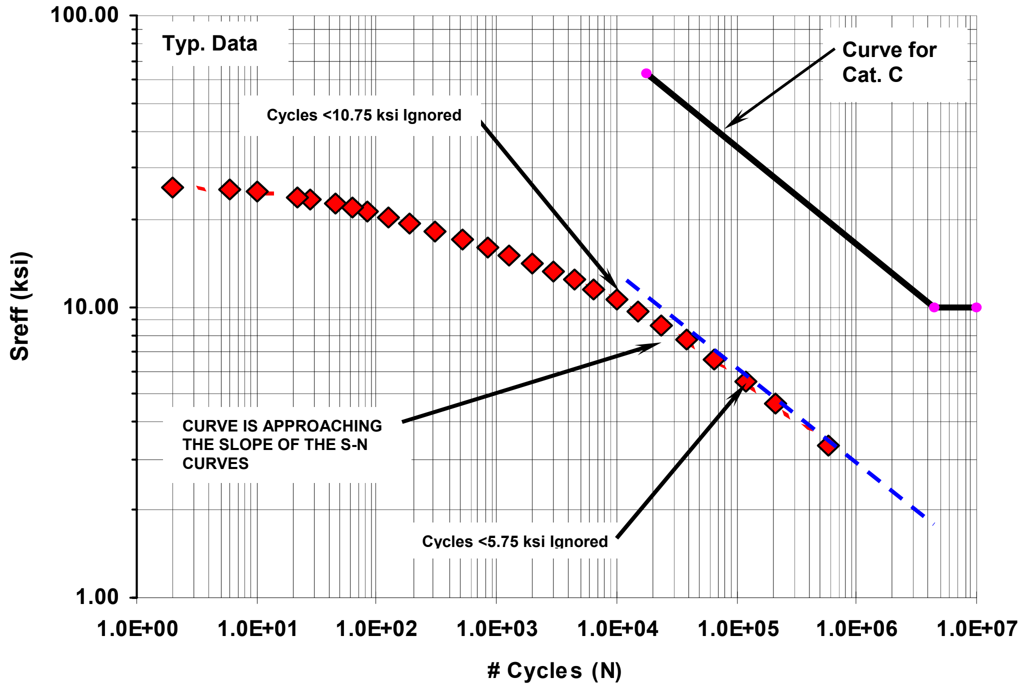

Figure B.1 – Effect of truncating cycles at different stress range cut off levels
(*Typical data from a stain gage at a fatigue sensitive detail*)

Figure B.1, shows the effect on the calculated effective stress range for several levels of truncation using typical field acquired long-term monitoring data collected from strain gage installed on a bridge. The data presented in Figure B.1 are also listed in Table B.1 showing the selected truncation level and its impact on the effective stress range.

As demonstrated by Figure B.1, as the truncation level decreases (from the lowest level), the effective stress range and corresponding number of cycles approaches the slope of the S-N curve for Category C, which is also plotted in Figure B.1 (i.e., a slope of –3 on a log-log plot). As long as the cut off level selected is consistent with the slope of the fatigue resistance curve, considering additional stress cycles at lower truncation levels does not improve the damage assessment and can therefore be ignored. As can be seen, using a truncation level as high as 10 ksi, the curve is nearly asymptotic to the slope of the S-N curves. Hence, an accurate prediction of the total fatigue life results.

It should also be noted that the load spectrum assumed in the AASHTO LRFD specifications for design was developed by only considering vehicles greater than about 20 kips [5]. Thus the AASHTO LRFD design also implicitly truncates and ignores stress cycles generated by lighter vehicles and vibration [6]. The observed frequency of stress cycles obtained from traffic counts is also consistent with the frequency of vehicles measured.

Cut Off (ksi)	Number Cycles > Cut Off Value	S_{reff} (ksi)
0.75	575,867	3.3
2.75	117,869	5.5
4.75	37,842	7.6
6.75	15,112	9.6
8.75	6,547	11.5
10.75	2,938	13.3
12.75	1,284	15.1
14.75	509	17.0
16.75	191	19.3
18.75	85	21.3
20.75	45	22.6
22.75	22	23.9
24.75	6	25.1
25.75	2	25.7

Table B.1 – Calculated effective stress ranges using different stress range cut off levels
Only every other data shown in Figure B.1 is shown for brevity

The maximum stress ranges listed in the tables developed in the body of this report were determined from the rainflow count. According to rainflow cycle counting procedures, the peak and valley that comprise the maximum stress range may not be the result of a single loading event and may in fact occur hours apart. In other words, an individual truck did not *necessarily* generate the maximum stress range shown in the tables. This is particularly true of distortion induced stresses that are subjected to reversals in stress due to eccentricity of the loading. In many cases, it was possible to identify this maximum stress range with a specific vehicle passage, but in other cases, the maximum rainflow stress range exceeded the maximum stress range from any individual vehicle. During the remote long-term monitoring program, the stress-range histograms were updated every ten minutes. Hence, the longest interval between nonconsecutive peaks and valleys is ten minutes.

References:

1. Miner, M.A., *Cumulative Damage in Fatigue*, Journal of Applied Mechanics, Vol. 1, No.1, Sept., 1945.
2. Downing S.D., Socie D.F., *Simple Rainflow Counting Algorithms*, International Journal of Fatigue, January 1982.
3. Fisher, J.W., Nussbaumer, A., Keating, P.B., and Yen, B.T., *Resistance of Welded Details Under Variable Amplitude Long-Life Fatigue Loading, NCHRP Report 354*, National Cooperative Highway Research Program, Washington, DC, 1993.
4. *Steel Structures – Material and Design*, Draft International Standard, International Organization for Standardization, 1994.
5. Schilling, C.G., *Variable Amplitude Load Fatigue, Task A - Literature Review: Volume I - Traffic Loading and Bridge Response*, Publication No. FHWA-RD-87-059, Federal Highway Administration, Washington, DC, July 1990.
6. Moses, F., Schilling, C.G., Raju, K.S., *Fatigue Evaluation Procedures for Steel Bridges, NCHRP Report 299*, National Cooperative Highway Research Program, Washington, DC, 1987.

Appendix C

Stress-range Histograms For Long-term Monitoring (non-truncated)

Span 34 & Span 35

Avg. Stress Range (ksi)	CH_4 (ksi)	CH_5 (ksi)	CH_12 (ksi)	CH_13 (ksi)	CH_15 (ksi)	CH_16 (ksi)	CH_23 (ksi)	CH_24 (ksi)	CH_25 (ksi)	CH_26 (ksi)
0.25	156	229	94	257	356	545	361	262	355	316
0.75	72335	164578	58723	371932	300903	1020805	1162609	819064	755987	394365
1.25	10019	36226	6896	99724	41962	185154	255394	179570	152460	123390
1.75	1167	11015	1483	36900	14752	59599	99852	69436	79749	76543
2.25	72	5312	327	16886	6601	26051	60257	41476	54885	45002
2.75	9	1225	132	8150	3241	12673	45746	30620	28839	21716
3.25	2	298	13	4131	2120	6785	37043	24443	15414	10146
3.75	1	80	6	2432	1428	3979	28179	18786	7385	4416
4.25	1	14	1	1561	788	2408	19104	13473	3689	2408
4.75	0	7	1	1030	457	1225	11943	8553	2127	1982
5.25	0	3	1	677	262	627	8063	5612	1777	1512
5.75	1	0	0	421	173	377	5334	3726	1487	1008
6.25	0	1	0	280	153	210	3581	2531	1095	486
6.75	0	0	0	179	85	162	2459	1771	628	211
7.25	0	0	0	146	52	94	1807	1390	291	83
7.75	0	0	0	77	20	46	1472	1079	142	23
8.25	0	0	0	53	10	21	1223	844	51	14
8.75	0	0	0	20	8	6	1028	649	16	7
9.25	0	0	0	12	2	4	779	582	12	4
9.75	0	0	0	5	0	5	1270	890	6	0
10.25	0	0	0	0	0	0	147	43	2	0
10.75	0	0	0	0	0	0	93	27	0	0
11.25	0	0	0	0	0	0	74	17	0	0
11.75	0	0	0	0	0	0	34	13	0	0
12.25	0	0	0	0	0	0	22	9	0	0
12.75	0	0	0	0	0	0	12	4	0	0
13.25	0	0	0	0	0	0	5	0	0	0
13.75	0	0	0	0	0	0	3	1	0	0

14.25	0	0	0	0	0	0	9	1	0	0
14.75	0	0	0	0	0	0	4	1	0	0
15.25	0	0	0	0	0	0	2	2	0	0
16.25	0	0	0	0	0	0	2	0	0	0
16.75	0	0	0	0	0	0	1	0	0	0
17.25	0	0	0	0	0	0	0	0	0	0
17.75	0	0	0	0	0	0	0	0	0	0
18.25	0	0	0	0	0	0	1	0	0	0
18.75	0	0	0	0	0	0	0	0	0	0
19.25	0	0	0	0	0	0	0	0	0	0
19.75	0	0	0	0	0	0	4	0	0	0

Span 34 & Span 35, (cont’d)

(ksi)	CH_28	CH_29	CH_39	CH_40	CH_41	CH_44	CH_45	CH_46	CH_47	CH_50	CH_53	CH_54	CH_55
0.25	(ksi)	(ksi)	(ksi)	(ksi)	(ksi)	(ksi)	(ksi)	(ksi)	(ksi)	(ksi)	(ksi)	(ksi)	(ksi)
0.75	236	73	153	219	265	216	399	179	418	143	152	178	216
1.25	318661	215449	150700	195737	174991	150297	527996	209154	810062	169772	227005	137015	193218
1.75	109511	47737	40944	38552	35494	14018	96326	38020	121809	9497	32302	34712	44660
2.25	32745	7813	9505	12191	12020	2326	35360	11789	54368	931	4813	11370	17709
2.75	13796	1087	2014	4595	4118	321	16751	3507	22015	108	885	5122	6359
3.25	5702	129	473	1381	988	82	10405	1052	13419	12	89	977	3194
3.75	2896	10	141	395	390	40	6324	356	7914	1	5	184	609
4.25	2146	0	35	202	185	13	2898	140	5335	0	3	45	134
4.75	1140	1	5	102	106	3	1001	60	3165	0	0	15	42
5.25	455	0	1	32	58	0	414	28	1263	0	1	6	16
5.75	149	1	3	12	34	0	208	15	596	0	0	0	7
6.25	32	0	1	0	24	1	96	10	339	0	0	0	0
6.75	10	0	0	0	21	0	35	3	167	0	1	0	1
7.25	1	1	1	0	12	0	20	3	83	0	0	0	0
7.75	0	0	0	1	2	0	7	1	32	0	0	0	0
8.25	0	0	0	0	20	0	4	1	17	0	0	0	0
8.75	0	0	0	0	2	0	2	0	13	0	0	0	0
9.25	0	0	0	0	1	0	4	0	4	0	0	0	0
9.75	0	0	0	0	1	0	1	0	1	0	0	0	0
10.25	0	0	0	0	4	0	0	0	1	0	0	0	0
10.75					0		2		0				
11.25					0		0		0				
11.75					0		1		0				
12.25					0		3		0				

Span 36 & Span 38

Avg. Stress Range (ksi)	CH_2 (ksi)	CH_3 (ksi)	CH_4 (ksi)	CH_5 (ksi)	CH_6 (ksi)	CH_7 (ksi)	CH_8 (ksi)	CH_9 (ksi)	CH_10 (ksi)	CH_16 (ksi)
0.25	79	64	2	9	35	2	3	18	42	50
0.75	169154	59025	1835	27968	15302	2519	1741	18466	37239	34452
1.25	40178	6728	45	701	557	27	47	626	2264	3602
1.75	8274	994	3	27	10	1	3	13	124	421
2.25	1736	88	1	5	5	0	1	0	2	134
2.75	257	13	0	0	2	0	0	1	0	11
3.25	29	6	0	1	2	0	0	0	0	0
3.75	1	0	0	0	1	0	0	0	0	0
4.25	0	0	0	0	0	0	0	0	0	0
4.75	0	1	0	0	6	0	0	0	0	0
5.25	0	0	0	0	0	0	0	0	0	0
5.75	0	0	0	0	0	0	0	0	0	0
6.25	0	0	0	0	0	0	0	0	0	0
6.75	0	0	0	0	0	0	0	0	0	0
7.25	0	0	0	0	0	0	0	0	0	0
7.75	0	0	0	0	0	0	0	0	0	0
8.25	0	0	0	0	0	0	0	0	0	0
8.75	0	0	0	0	0	0	0	0	0	0
9.25	0	0	0	0	0	0	0	0	0	0
9.75	0	0	0	0	0	0	0	0	0	0

Span 36 & Span 38 (cont'd)

Avg. Stress Range (ksi)	CH_17 (ksi)	CH_18 (ksi)	CH_20 (ksi)	CH_21 (ksi)	CH_22 (ksi)	CH_24 (ksi)	CH_25 (ksi)	CH_28 (ksi)	CH_29 (ksi)	CH_30 (ksi)
0.25	36	1	34	17	89	5	23	19	38	78
0.75	27902	154	42120	20653	64162	6842	24955	34281	60690	87994
1.25	2108	4	5677	3081	8963	362	3506	4226	6022	22625
1.75	221	0	395	355	2375	16	158	510	662	5061
2.25	26	0	160	158	500	0	5	70	36	1315
2.75	1	0	56	68	43	1	0	22	0	360
3.25	0	0	4	15	1	0	0	4	0	65
3.75	0	0	0	0	0	0	0	0	0	10
4.25	0	0	0	0	0	0	0	1	0	5
4.75	0	0	0	0	0	0	0	1	0	0
5.25	0	0	0	0	0	0	0	1	0	0
5.75	0	0	0	0	0	0	0	0	0	0
6.25	0	0	0	0	0	0	0	0	0	0
6.75	0	0	0	0	0	0	0	0	0	0
7.25	0	0	0	0	0	0	0	0	0	0
7.75	0	0	0	0	0	0	0	0	0	0
8.25	0	0	0	0	0	0	0	0	0	0
8.75	0	0	0	0	0	0	0	0	0	0
9.25	0	0	0	0	0	0	0	0	0	0
9.75	0	0	0	0	0	0	0	0	0	0

Span 36 & Span 38, (cont'd)

Avg. Stress Range (ksi)	CH_31 (ksi)	CH_33 (ksi)	CH_34 (ksi)	CH_44 (ksi)	CH_45 (ksi)	CH_46 (ksi)	CH_48 (ksi)	CH_49 (ksi)	CH_50 (ksi)	CH_51 (ksi)
0.25	84	61	126	36	112	143	239	280	328	171
0.75	69473	36196	91952	24225	112306	160991	809916	175155	647298	263884
1.25	10222	5421	31687	690	20057	19089	181756	30316	124527	45116
1.75	2591	583	8917	13	5326	3936	65861	7862	56263	12406
2.25	417	22	3545	0	1047	1035	29883	2391	24251	4168
2.75	11	3	1095	0	253	220	15143	791	11895	2133
3.25	0	1	232	0	119	80	7500	408	6002	1304
3.75	0	0	56	0	27	32	3873	208	3270	548
4.25	0	0	12	0	2	2	2322	149	1813	148
4.75	0	0	3	0	1	0	1494	105	958	27
5.25	0	0	0	0	0	0	1104	106	535	9
5.75	0	0	0	0	0	0	897	90	271	1
6.25	0	0	0	0	0	0	696	67	185	0
6.75	0	0	0	0	0	0	523	765	110	1
7.25	0	0	0	0	0	0	293	0	61	0
7.75	0	0	0	0	0	0	152	0	38	0
8.25	0	0	0	0	0	0	89	0	27	0
8.75	0	0	0	0	0	0	25	0	11	0
9.25	0	0	0	0	0	0	14	0	7	0
9.75	0	0	0	0	0	0	15	0	2	0

Span 36 & Span 38, (cont'd)

Avg. Stress Range **(ksi)**	**CH_55**	**CH_56**	**CH_57**	**CH_58**	**CH_59**	**CH_60**
0.25	45	46	49	40	162	170
0.75	32547	41890	141994	89174	176434	150751
1.25	3916	4072	22014	11152	33031	28315
1.75	605	445	4553	1503	12438	10491
2.25	135	64	1725	195	4460	3594
2.75	40	8	2191	31	1410	606
3.25	4	0	910	10	246	104
3.75	1	1	366	2	46	30
4.25	0	0	268	0	16	3
4.75	0	0	432	0	3	1
5.25	0	0	0	1	0	0
5.75	0	0	0	0	0	0
6.25	0	0	0	0	0	0
6.75	0	0	0	0	0	0
7.25	0	0	0	0	0	0
7.75	0	0	0	0	0	0
8.25	0	0	0	0	0	0
8.75	0	0	0	0	0	0
9.25	0	0	0	0	0	0
9.75	0	0	0	0	0	0

Span 45

Avg. Stress Range (ksi)	CH_4 (ksi)	CH_5 (ksi)	CH_6 (ksi)	CH_7 (ksi)	CH_8 (ksi)	CH_9 (ksi)	CH_10 (ksi)	CH_11 (ksi)	CH_12 (ksi)	CH_13 (ksi)
0.25	163	151	28	143	112	131	102	27	60	58
0.75	246486	142355	24071	229168	159059	77489	103217	26414	38743	33279
1.25	83085	32723	670	69897	29950	14098	14966	2919	6796	5009
1.75	37322	9057	5	26777	8025	3351	3082	294	769	644
2.25	15995	3322	0	12456	2899	367	976	8	238	192
2.75	8306	694	0	5915	1101	24	261	0	136	61
3.25	4444	116	0	3206	417	1	58	0	24	1
3.75	2405	21	0	1823	90	2	23	0	1	0
4.25	1409	1	0	1100	8	1	4	0	1	0
4.75	935	2	0	740	3	1	4	0	0	0
5.25	631	1	0	465	0	1	0	0	0	0
5.75	434	2	0	289	0	2	3	0	2	0
6.25	299	1	0	184	0	0	0	0	1	0
6.75	184	1	0	82	0	1	0	0	0	0
7.25	102	2	0	34	0	0	0	0	0	0
7.75	48	0	0	14	0	0	0	0	0	0
8.25	22	1	0	5	0	0	0	0	2	0
8.75	10	0	0	3	0	1	0	0	1	0
9.25	2	0	0	0	0	0	0	0	0	0
9.75	4	1	0	0	0	0	0	0	0	0

Span 45 (cont'd)

Avg. Stress Range (ksi)	CH_15 (ksi)	CH_19 (ksi)	CH_20 (ksi)	CH_21 (ksi)	CH_22 (ksi)	CH_25 (ksi)	CH_26 (ksi)	CH_27 (ksi)	CH_28 (ksi)	CH_29 (ksi)
0.25	18	148	149	99	130	85	118	25	87	68
0.75	15629	29975	141777	26191	43811	79512	158358	31570	142696	43659
1.25	1785	2834	28278	2095	5338	16273	41154	5148	35621	6585
1.75	159	372	7384	200	866	4225	7917	996	10518	700
2.25	32	49	1748	13	101	1382	1706	274	2648	18
2.75	4	3	391	0	6	489	329	63	769	2
3.25	0	0	128	0	1	179	40	14	198	5
3.75	0	0	32	0	0	77	3	6	57	0
4.25	0	0	10	0	0	16	1	4	23	0
4.75	0	0	1	0	0	8	0	1	5	5
5.25	0	0	0	0	0	1	0	0	2	0
5.75	0	0	0	0	0	0	0	1	0	1
6.25	0	0	0	0	0	0	0	0	1	0
6.75	0	0	0	0	0	0	0	0	0	0
7.25	0	0	0	0	0	0	0	0	0	0
7.75	0	0	0	0	0	0	0	0	0	0
8.25	0	0	0	0	0	0	0	0	0	0
8.75	0	0	0	0	0	0	0	0	0	0
9.25	0	0	0	0	0	0	0	0	0	0
9.75	0	0	0	0	0	0	0	0	0	0

Span 45, (cont'd)

Avg. Stress Range **(ksi)**	**CH_30 (ksi)**	**CH_32 (ksi)**	**CH_33 (ksi)**	**CH_34 (ksi)**	**CH_35 (ksi)**	**CH_36 (ksi)**	**CH_37 (ksi)**	**CH_38 (ksi)**	**CH_39 (ksi)**	**FB1_Bot. (ksi)**	**FB2_Top (ksi)**
0.25	150	186	286	273	243	171	48	60	0	41	0
0.75	138767	245570	610388	659704	338715	300057	248672	149540	2810	38430	396
1.25	35551	77908	215549	234267	155442	132520	60132	35726	16	3719	56
1.75	12222	22573	112005	122153	87348	58975	6073	11347	9	919	18
2.25	4181	8397	69914	73179	39787	21272	374	4163	4	224	12
2.75	2389	3606	51022	53065	18664	8752	16	1578	3	84	9
3.25	632	1424	35328	41175	10230	3405	3	719	2	34	4
3.75	94	534	20444	26857	4506	1770	2	180	0	9	5
4.25	20	174	11415	15536	2446	679	0	35	2	3	3
4.75	2	56	7669	9305	1661	210	0	12	0	6	2
5.25	0	17	5020	6594	727	53	0	2	0	1	0
5.75	0	1	3050	4184	311	10	0	0	1	1	2
6.25	0	1	1914	2575	138	6	0	2	1	1	0
6.75	0	0	1560	1754	49	3	0	0	0	1	0
7.25	0	0	1121	1372	32	2	0	1	0		
7.75	0	0	714	969	20	0	0	0	0		
8.25	0	0	437	654	18	0	0	0	1		
8.75	0	0	246	411	22	0	0	0	0		
9.25	0	0	152	250	20	0	0	0	0		
9.75	0	0	92	854	331	0	0	0	0		
			17	29				0			
			11	20				0			
			6	9				0			
			1	6				0			
			0	4				0			
			2	3				0			
			0	0				0			
			1	1							

Appendix D

Weight In Motion Study

D.0 Introduction and Objective

Weight-In-Motion (WIM) devices have been used in the past to provide highway-use data mandated by the Federal Highway Administration (FHWA). The data are typically used for truck size and weight enforcement on highways as well as highway management and design. An ASTM Standard Specification E1318 "Standard Specification for Highway Weigh-In-Motion (WIM) Systems with User Requirements and Test Methods" has been developed for WIM system requirements and test methods on highways. However, no ASTM standards are currently available for WIM studies on bridges. This is primarily due to the complexity of interpolating WIM data collected from bridges. The complexity of interpolating the data results from variation in the dynamic interaction between moving vehicles and the bridge.

Recognizing the high degree of variability in WIM data collected from bridges, video and strain gage data were used in conjunction with the WIM data with the objective of correlating certain events in the time-history response of a particular strain gage (strain gage data), with the axle weight producing such stress (WIM data) and the type of vehicle causing the stress, including multiple presence of vehicles (video data). This objective was achieved by identifying the WIM system to be used, calibrating and installing the system on the bridge, installing two video camera to capture video images, reducing and analyzing the WIM data collected, and finally correlating the time-history data of the strain gages with collected video images and WIM data.

D.1 System Identification

D.1.1 Selected System

Several types of WIM systems are commercially available and have been used by engineers and researchers in various WIM studies. The system identified for this study was chosen based on its cost, the level of performance and accuracy needed, and in accordance with ASTM E1318-02. The system was also selected based on its capability for providing information on vehicle classification, speed, time, and weight for up to six lanes (total number of lanes on the Throgs Neck Bridge) and in accordance with the 13 vehicle classification listed by FHWA. The TCC 540 WIM manufactured by International Road Dynamics (IRD), which is a portable weight-in-motion counter and classifier system, was chosen for this project. The sensors used for vehicles weigh and classifications are piezoelectric and loop sensors, respectively. Each lane was instrumented with two loops and a piezo in a loop-piezo-loop configuration. The loop sensors were used for truck counting, speed, and classification, while the piezo sensors were used for truck weight measurements. Piezo sensors are typically used to detect vehicle weight by measuring the change in voltage in the sensor due to the pressure induced on the sensors as a result of crossing of a vehicle. Loop sensors on the other hand, measure axle spacing when the magnetic field created by the sensor is interrupted due to the crossing of a vehicle. The piezos and the loops were taped down to the roadway with special tape supplied by IRD. Figure D.1 shows typical installation of WIM sensors and data acquisition (TCC 540) on a roadway. It is important to note and as previously discussed, no ASTM standards are available for collecting WIM data from bridges. Therefore, the level of accuracy listed by IRD for the TCC 540 WIM and the sensors corresponds to the level of accuracy if installation of the sensors was on a roadway or a highway and in accordance with ASTM E1318, which is $\pm 30\%$ for Type I sensors used.

Figure D.1 - Typical installation of TCC 540 WIM and sensors
(from http://products.irdinc.com/pdf/brochure/counter/540WIM_0303.pdf)

D.1.2 System Accuracy

The accuracy of the WIM data is highly dependent on the type of sensors used, the installation method (i.e., permanent versus temporary installation), the sequence at which the sensors are installed in a given lane (i.e., piezo-loop-piezo, loop-piezo-loop, etc.). The accuracy of the measurements is also influenced by factors such as the horizontal curvature of the roadway lane, longitudinal gradient and the cross slope of the road surface, the operation temperature, etc. Determining the exact degree of accuracy for WIM data collected from a bridge is a difficult task due to the high variability in the bridge/vehicle interaction as noted above.

As previously discussed, an accuracy level of $\pm 30\%$ is expected as specified by the ASTM Specification for Type I sensors (with loop-piezo-loop configuration), if the sensors were not installed on a bridge. An increase of the level of accuracy $\pm 15\%$ of the data could have possibly been achieved by using two piezo sensors per lane instead of one. The increase in accuracy is a result of averaging the axle weight of the passing vehicle measured by the two piezos. Using peizo-loop-piezo sensor configuration per lane would have required the use of two TCC 540 WIM systems, which would have significantly increased the cost of the project with uncertainty in the increase of the degree of accuracy. The uncertainty in the increase in the accuracy is due to the uncertainty related to vehicle/structure interaction.

Recognizing the difficulty in determining the exact degree of accuracy for the data collected, the data were filtered based on front axle weight, axle spacing, and vehicle speed. Vehicles with front axle weight higher than 20 kips were discarded. It is important to note that a recorded WIM front axle weight of 20 kips could have an error. However, knowing the expected axle spacing as specified by FHWA 13 vehicle classification was helpful in reducing such error. Also, WIM data for vehicles with speed of 20 miles per hour or below were discarded as recommended by IRD. When in doubt, video images were used to verify if the data recorded by the WIM are reasonable or not. For example, Figure D.2 shows a trail of vehicle crossing in the middle lane in the southbound direction on the morning of September 27, 2005. The WIM data corresponding to the video image show that a vehicle with 16-axle and GVW of 243.5 kips was passing over the sensors at the same time the video image was recorded. The image clearly shows that 14-axle trucks were not present on the bridge at that time, and therefore the WIM record for this event is faulty. It is important to note that although the speed of the vehicles exceeded 20 mph as recommended by IRD, the vehicles were closely spaced and produced unreliable WIM data for this event.

Figure D.2 – Trail of vehicles passing in the middle lane (Lane 5) in the southbound direction on September 27, 2005 at 10:38:07 AM

Time stamp	Lane #	Vehicle speed (mph)	# of axles	Total length (ft)	GVW (kips)
10:38:07	5	32.2	16	546.9	**243.5**

Table D.1 – Faulty WIM data for 16-axle truck traveling in the middle lane in the southbound direction on September 27, 2005 at 10:38:07 AM

D.2 Installation, Verification, and Calibration of WIM System and Video Camera

D.2.1 WIM System Temporary Installation and Verification

Prior to system mobilization to the site, system verification was conducted by Lehigh personal to assure that the system is functioning properly and verify its accuracy. The sensors were placed in the parking lot of the ATLSS Center in the same configuration to be used in the field during actual monitoring (i.e., loop-piezo-loop). The ATLSS field van (with known axle weight and spacing) was utilized for this initial verification process.

For system verification while onsite, the WIM sensors and system were installed on the bridge on the afternoon of August 9, 2005. Sensors were installed temporarily on the outside lane (Lane 6) in Span 33 near the expansion joint located between the anchorage span and Span 33 in the southbound direction using duct tape in a loop-piezo-loop configuration. The ATLSS field van was driven across the sensors a number of times to test the sensors and examine the consistency in the measured vehicle speed, number of axle, axle spacing, and axle weight. The results are summarized in Table D.2 below.

As listed in the table, the average Gross Vehicle Weight (GVW) of the first four passages is 0.9 kips. A randomly selected multiplier of 7 was assigned to the system (i.e., manual calibration) to increase the GVW values recorded by the piezo sensor, and to magnify the error in the measurements such that the consistency in the measured data could be examined. As shown in the table, introducing the multiplier resulted in an increase in the measured GVW. However, there were scatter in the data which could be attributed to the sensors being installed temporarily on the bridge (duct taped) in addition to the randomness associated in the bridge/vehicle interaction. For calibration during the one week monitoring, the system was permanently installed on the bridge and was set to auto calibration as discussed in Section D.2.2.

Passage Number	Front axle weight	Rear axle weight	GVW	Axle spacing
1	0.3	0.6	1.0	15.7
2	0.3	0.3	0.7	15.3
3	0.5	0.2	0.7	22.0
4	0.6	0.5	1.2	15.7
5	0.3	2.5	2.9	15.1
[3]Avg	0.43	0.4	0.9	17.2
After introducing a multiplier of 7				
6	0.2	0.2	0.4	17.0
7	0.2	0.2	0.4	17.7
8	2.2	2.5	4.8	15.9
9	2.5	0.2	2.7	15.2
10	0.2	2.4	2.6	15.5
11	0.2	9.2	9.4	15.5
12	5.3	2.3	7.6	15.8
13	0.2	4.3	4.5	15.5
14	0.2	2.3	2.5	15.9

Note:
1. All weight values are in kips
2. Axle spacing is in ft
3. The average is for the first four runs

Table D.2 – WIM data collected in the afternoon of August 9, 2005 with sensors installed on span 33 in the outside lane (Lane 6) in the southbound direction as the ATLSS field van passed over the installed sensors

D.2.2 WIM System Permanent Installation, Verification, and Calibration

After viewing the data shown above in Table D.2, a decision was made by the Project Engineer on site from Parsons Transportation Group to move the sensors from Span 33 and permanently install them on the anchorage span, since the anchorage span is stiffer than Span 33 and less vulnerable to dynamic vibration induced by random traffic. The middle lane (Lane 5) and the outside lane (Lane 6) were closed to traffic and the sensors were installed on the roadway 4 feet away from the expansion joint located at the beginning of the anchorage span between Span 33 and the anchorage span *(the installed sensors were a distance apart from the instrumented spans).*

After the sensors were installed, the ATLSS field van was again driven across the sensors to examine the consistency in the measured vehicle speed, number of axle, axle spacing, and axle weight. The results are summarized in Table D.3 below. Except where the front axle weight was measured to be 0.2 kips and 0.3 kips, the table shows consistency in the measured front and rear axle weight and axle spacing. The higher consistency in the data listed in Table D.3, when compared to that of Table D.2, could be attributed to the anchorage span being less vulnerable to vibration than Span 33 and to the sensors being permanently installed on the bridge using glue supplied by the manufacturer (not duct taped).

The GVW of the ATLSS field van was previously measured using a static scale and found to be equal to 3.5 kips, which means that a multiplier factor of 1.46 is needed to increase the calculated average GVW of 2.4 kips to 3.5 kips. The WIM system is manufactured where no multiplier is to be assigned to adjust the axle spacing. The calculated average axle spacing measured for the field van is 13.1 ft using sensors installed on the outside lane and 14.0 ft for sensors installed in the middle lane. The actual axle spacing measured is 13'-2 ½". Therefore, the calculated average axle spacing measurement using the outside lane sensors has an error of 1.6% and the calculated average axle spacing measurement using the middle lane sensors has an error of 6%. Because temperature, field conditions, and sensor performance change with time, the multiplier factor is also expected to change with time. Therefore, for the continuous monitoring, the WIM system was set to auto-calibrate based on the passage of class 9 (5-axle) trucks with front axle weight ranging between 9 kips-12 kips (i.e., an automatic multiplier factor is determined by the system to account for sensor measurement drifting due to varying field conditions and sensor wear).

Outside lane (Lane 6)			
Front axle weight	**Rear axle weight**	**GVW**	**Axle spacing**
1.2	1.2	2.4	13
0.2	1.2	1.5	12.3
1.2	1.2	2.4	13.3
1.2	1.2	2.4	13.8
1.1	1.2	2.3	12.4
Avg. front axle weight	**Avg. rear axle weight**	**Avg. gross vehicle weight**	**Avg. axle spacing**
1.2	**1.2**	**2.4**	**13.1**
Middle lane (Lane 5)			
1.2	1.2	2.4	14
1.2	1.2	2.4	13.9
0.3	1.2	1.5	13.8
1.2	1.2	2.4	13.7
1.2	1.2	2.4	13.7
1.2	1.2	2.4	14.6
Avg. front axle weight	**Avg. rear axle weight**	**Avg. gross vehicle weight**	**Avg. axle spacing**
1.2	**1.2**	**2.4**	**14.0**

Note:
1. All weight values are in kips
2. Axle spacing is in ft
3. Average values were calculating by disregarding the rows containing front axle weight of 0.2 kips and 0.3 kips
4. A multiplier factor of 1.46 is required to increase the average GVW from 2.4 kips to 3.5 kips

Table D.3 – WIM data collected in the afternoon on August 9, 2005 by sensors installed on the anchorage span in Lane 2 and Lane 3 in the southbound direction as the ATLSS field van passed over the installed sensors

The data listed in Table D.3 show that consistency of the data was achieved when the sensors were installed permanently on the anchorage span. On the night of August 9, 2005, six 5-axle test trucks with known configuration and axle weight were brought to the site for further verification of the consistency in the performance of the installed sensors located on the anchorage span in Lane 2 and Lane 3. The gross vehicle weight for all trucks was reported to be approximately 80 kips. For initial verification, it was decided that three runs of three different test trucks would be run in each lane. That is, Truck 1, Truck 2, and Truck 3 were driven in Lane 3 and Truck 4, Truck 5, and Truck 6 were driven in Lane 2. During verification of the sensors installed on Lane 2 and as Truck 6 was passing over the sensors, the WIM system indicated that the test truck crossing the sensors was a 6-axle truck. The truck driver backed up the truck in Lane 3 and stopped to investigate if the sixth axle of the truck was in the "up" or "down" position. It was found that the tires were in the "up" position on one side of the axle and in the "down" position on the other side of the axle. An attempt by the truck driver to completely raise the axle resulted in the axle being locked in place in the "down" position directly over the sensors installed in Lane 3. With the axle being locked, the test truck was stuck in place directly over the sensors. The driver attempted to move the truck forward. Because the axle was locked, large shearing force was generated and acted directly on the sensors resulting in ripping off the wires of a loop and a piezo sensor and malfunctioning of the other loop sensors. The result of the sensor performance verification using the six 5-axle trucks is summarized in Table D.4. A review of the data listed in Table D.4 shows consistency in the measured GVW of the trucks. It is important to note that all six trucks were reported to have GVW of approximately 80 kips. The exact weight of each truck was not exactly known prior to their passage over the sensor (i.e., the trucks used are not the same ones listed in Chapter 3, which were used in the controlled load test.)

Outside lane (Lane 6) South bound						
Truck #	**First axle weight**	**Second axle weight**	**Third axle weight**	**Fourth axle weight**	**Fifth axle weight**	**GVW**
1	3.0	8.4	8.5	10.0	11.8	42.0
2	5.5	5.1	5.5	13.2	6.6	36.1
3	7.8	4.7	3.7	8.2	11.5	36.2
Middle lane (Lane 5) South bound						
Truck #	**First axle weight**	**Second axle weight**	**Third axle weight**	**Fourth axle weight**	**Fifth axle weight**	**GVW**
4	4.5	4.5	3.1	5.4	5.0	22.8
5	3.8	2.8	2.5	4.9	6.9	21.2
6	Axle locked on installed sensors in Lane 3					

Note:
1. All weight values are in kips

Table D.4 – WIM data collected by sensors installed on the anchorage span in Lane 2 and Lane 3 in the southbound direction as six test trucks passed over the installed sensors

On the night of August 10, 2005, the damaged sensors were reinstalled on the roadway in the southbound direction. In addition, sensors installation in the southbound direction was completed with the installation of sensors in the inside lane (Lane 1). On the night of August 11, the remaining sensors were installed in the northbound direction and the system was set for random monitoring. A schematic of the location of the permanently installed sensors on the anchorage span is shown in Figure D.3. Figure D.4 shows the sensors installed on the anchorage span in the southbound direction.

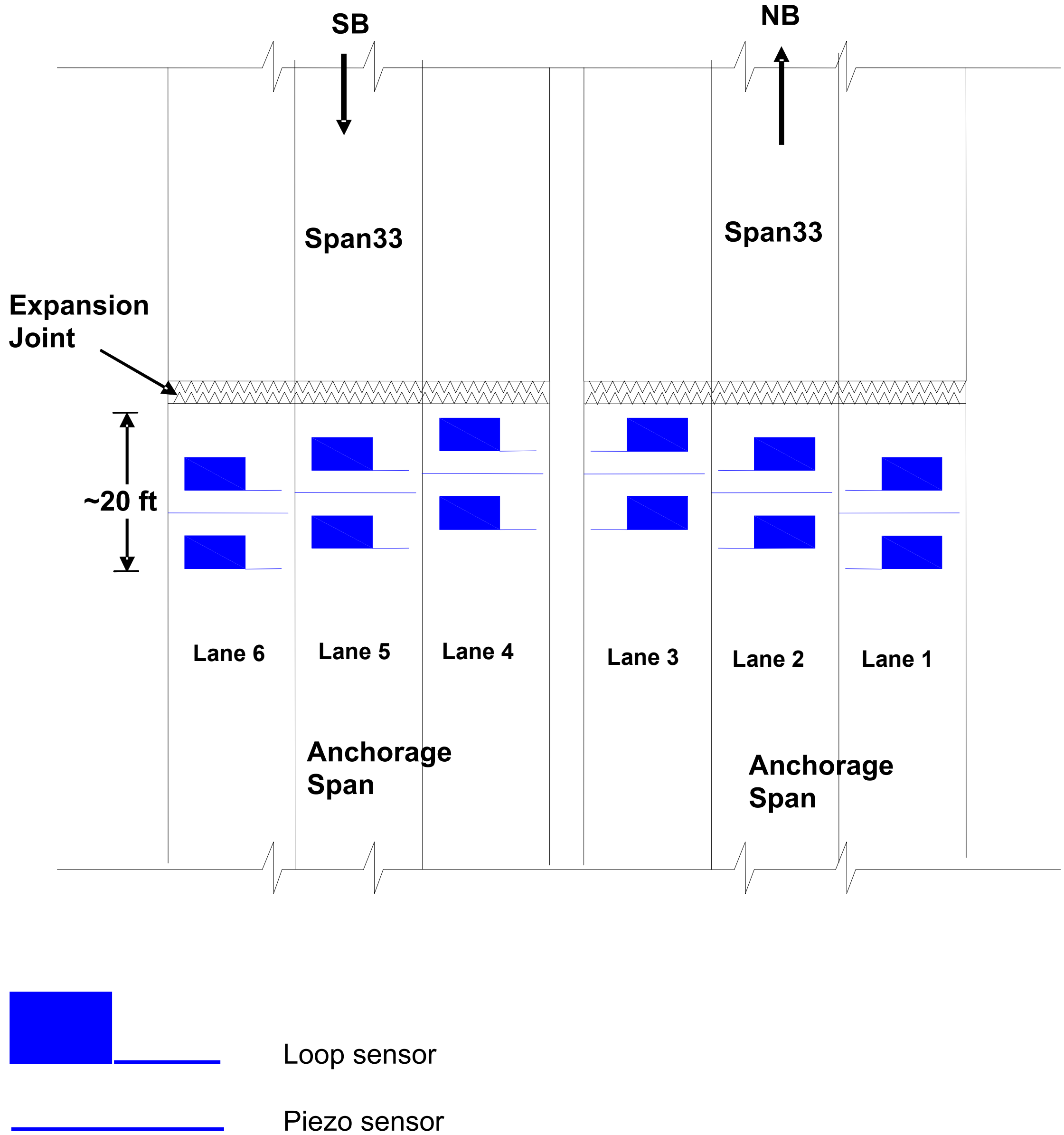

Figure D.3 – Location of loop and piezo sensors installed on the anchorage span in the northbound and southbound directions

Figure D.4 – Location of loop and piezo sensors installed on the anchorage span in the southbound direction

On Monday, August 15, the data collected from August 11 through August 15 was retrieved and viewed. A large scatter was evident in the data. It was believed that the scatter might have been caused by the dynamic vibration of the bridge, coupled with the high variability in the bridge-vehicle interaction, which depends not only on the dynamic characteristics of the bridge, but also the dynamic response of the vehicle crossing over the sensors. It was decided to conduct more calibration of the sensors during the controlled load testing, which was scheduled on the night of same day. After conducting the controlled load tests and calibration of the WIM sensors in Lane 1, Lane 2, and Lane 3 on the northbound, the data were retrieved. It was found that all piezo sensors were not functioning and the WIM sensors in all three lanes did not collect any data during the calibration period. Malfunctioning of all piezo sensors installed on the northbound suggests that the problem could have been related to the sensors, the hardware, or the software. The WIM System was then removed and brought to the ATLSS Center to perform some diagnostics and determine the reasons for the poor performance of the system. After evaluating the WIM data collected by the system while on site, it was decided to send the WIM system to the manufacturer (IRD) for further evaluation. IRD determined that the poor performance of the system was due to hardware and software problems. Another round of sensor installation and calibration was scheduled for September 20, 2005. The old sensors were removed and new sensors were installed at the same location. A three-axle truck loaded with salt (Figure D.5) and weighed on site using portable scales was brought to the site to be driven over the sensors and verify that the sensors are operating properly. As previously noted, the system was set for auto calibration such that the proper multiplication factor was automatically assigned to the sensors based on the average reading of the passage of fifteen 5-axle trucks over the sensors with measured front axle weight between 9 kips to 12 kips. The system was left for a continuous monitoring of one week from September 22, 2005 until September 30, 2005.

Figure D.5 – 3-axle truck supplied by the TBTA, loaded with salt, and driven over the sensors for system verification

D.3 Installation of video Camera

Two video cameras were installed such that video data can be integrated with WIM data and strain gage data to correlate certain events in the time-history data with the axle weight producing such stress (WIM data) and the type of vehicle causing the stress (video data). The first camera was installed on the guard rail of the bridge cables as shown in Figure D.6. The camera was installed such that clear images of vehicles crossing over the WIM sensors could be captured. A second camera was mounted on the overhead gantry at the anchorage span in the southbound direction. The camera was positioned to capture images of vehicles passing over Span 34 and Span 35 in the northbound direction such that a correlation between vehicles crossing over the spans, the recorded WIM data and the stress time-history data can be made. The time stamp of the video images, stress-time history data, and the WIM data was "synced" to allow efficient comparison of the data.

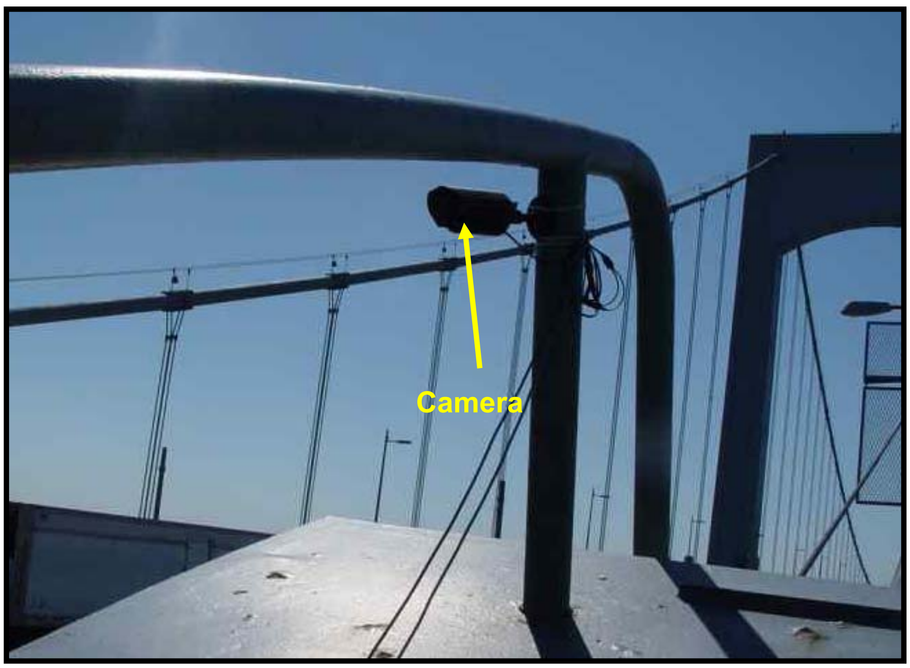

Figure D.6 – Camera installed on the guard rail of the bridge cables

D.4 Data Reduction and Analysis

D.4.1 Vehicle Distribution by Weight

Figure D.7 shows vehicle weight distribution in the northbound and southbound directions during the one week monitoring period. As shown in the figure, vehicles with GVW higher than 200 kips were recorded by the WIM system. The figure shows that except for the weight range of 0-10 kips and for up to the weight range of 80-90 kips, higher number of vehicles was recorded to be traveling in the northbound direction than the southbound direction. For the weight range from 90-100 kips and up to higher than 200 kips, higher number of vehicles was recorded to be traveling in the southbound direction than in the northbound direction as shown by the inset in the figure. It is important to note that the WIM data were filtered before being plotted based on the criterion listed above. Although, the histogram shows vehicles above 200 kips were crossing over the bridge, it is likely that some of these events do not represent the actual static weight of the vehicle crossing since vehicle/bridge interaction has an influence on the GVW recorded by the WIM sensors as previously noted.

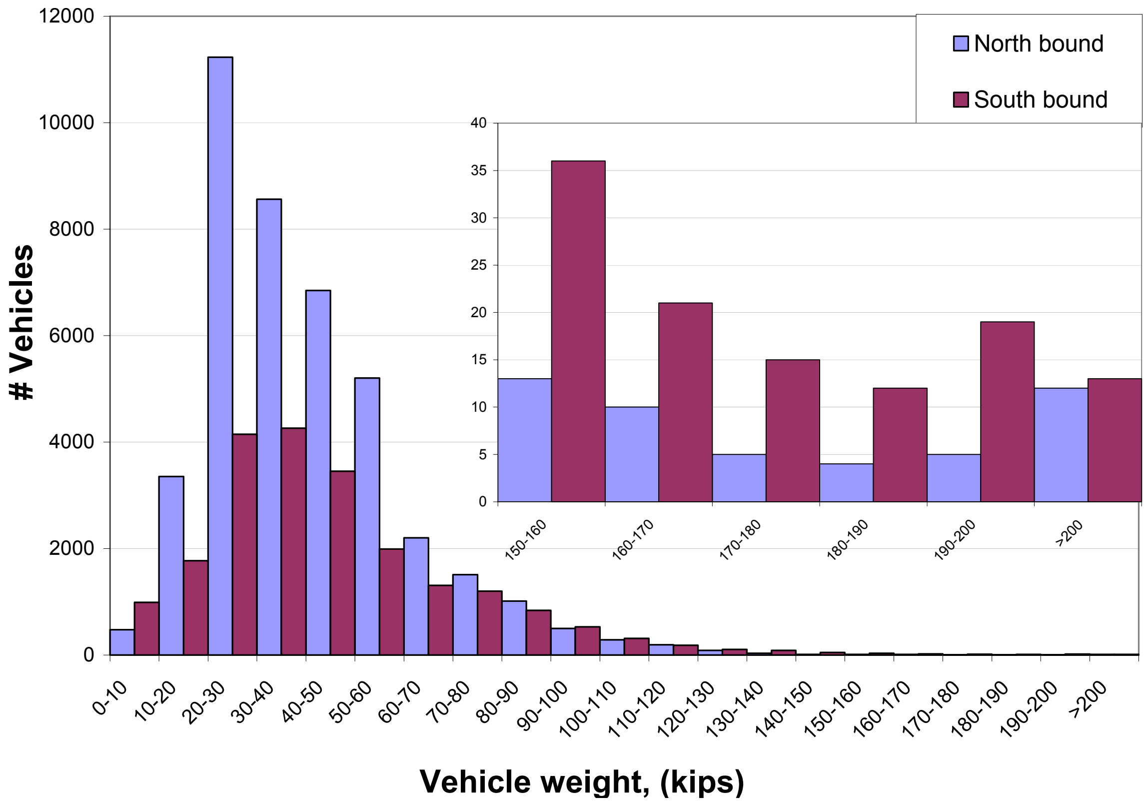

Figure D.7 – Vehicle weight distribution in the northbound and southbound directions during the monitoring period (September 22, 2005 until September 30, 2005)

D.4.2 Vehicle Distribution by Lane

Figure D.8 shows the vehicle weight distribution by lane. The figure shows that in all weight ranges, including heavy trucks, a higher number of vehicles traveled in the middle lane than in the inside or outside lane in the northbound direction. It is well known that trucks and heavy vehicles usually travel in the outside lanes. The higher number of heavy vehicles traveling in the middle lane could be primarily due to lane closure of the outside lane, possibly for bridge maintenance, which could have forced vehicles to travel in the middle lane. A similar conclusion can be drawn for vehicles traveling in the southbound direction as shown in Figure D.9. Again, it is possible that some of these events do not represent the actual static weight of the vehicle crossing since vehicle/bridge interaction has an influence on the GVW recorded by the WIM.

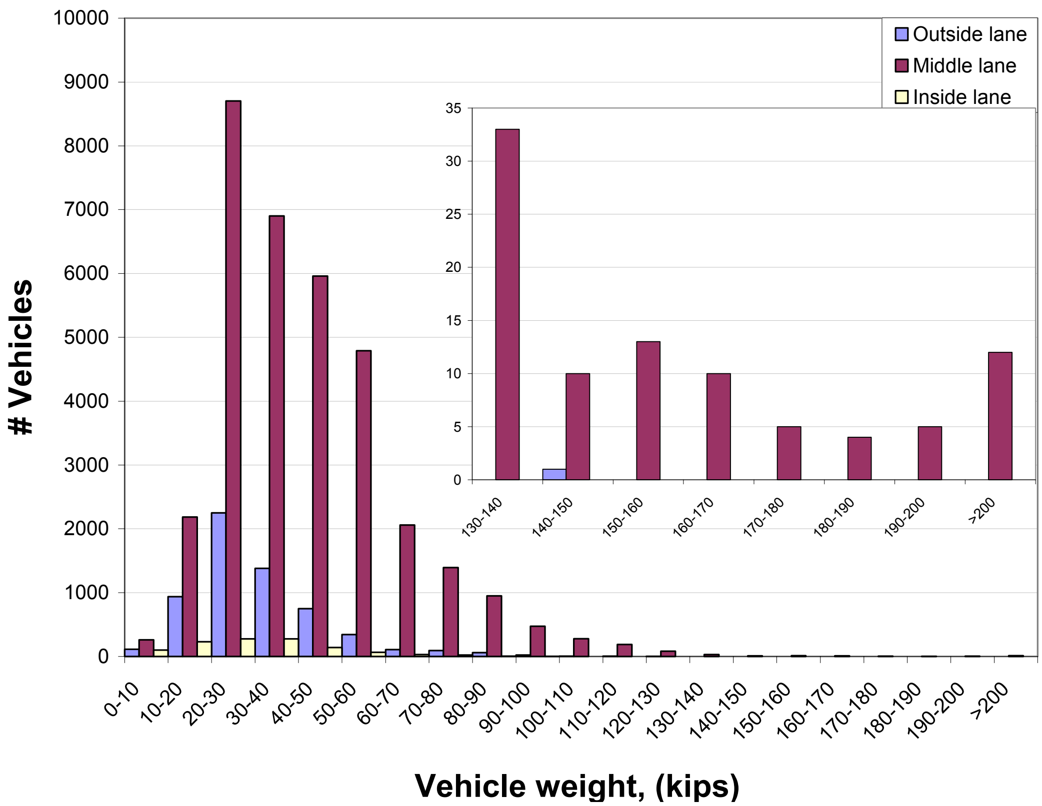

Figure D.8 – Vehicle weight distribution in the outside, middle, and inside lanes in the northbound direction during the monitoring period (September 22, 2005 until September 30, 2005)

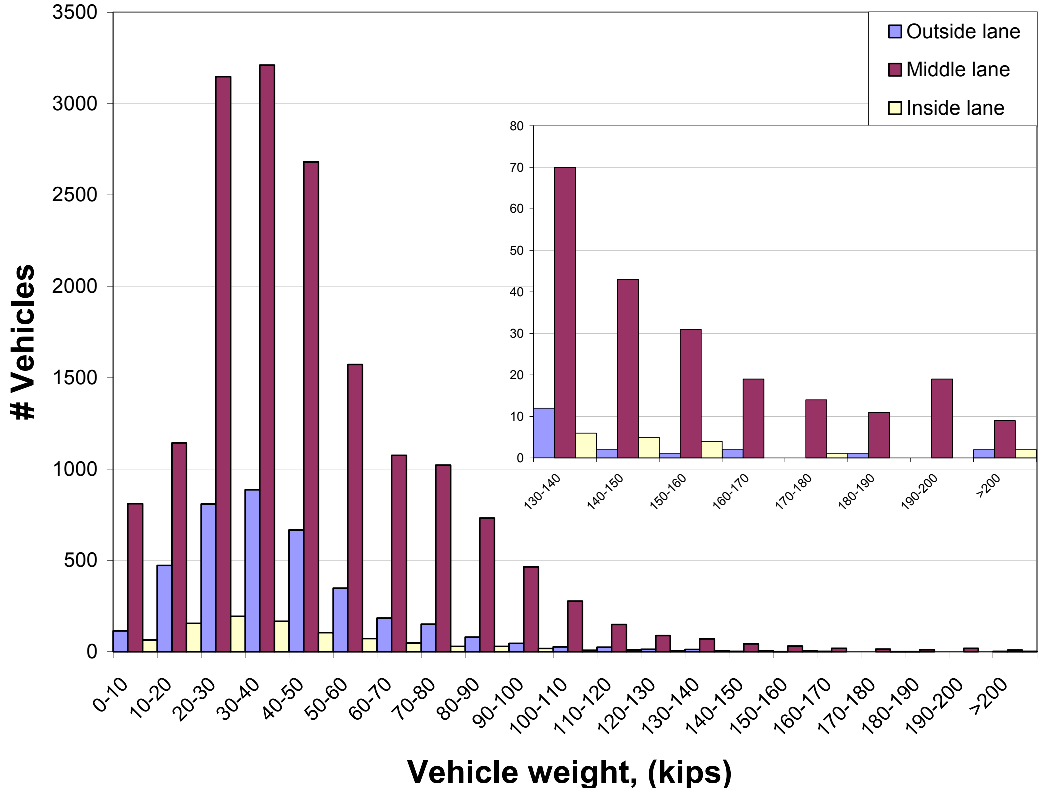

Figure D.9 – Vehicle weight distribution in the outside, middle, and inside lanes in the southbound direction during the monitoring period
(September 22, 2005 until September 30, 2005)

D.5 Vehicle Classification

D.5.1 WIM and Video Correlation

Vehicles with axles up to 7-axles were recorded by the video camera and the WIM sensors. It is important to note that it is widely known that some trucks cross over bridges with the lift axle in the up position. For example, a 4-axle or a 5-axle truck may in fact be 5-axle and 6-axle trucks, respectively, with the lift axle up. Such possibility could explain some high loads on the rear tandem, however can not be accounted for using the installed sensors. As previously noted, the video time stamp and the WIM time stamp were "synced" such that video images, which correspond to a certain WIM data at a given time stamps can be presented. Figure D.10 shows 2-axle vehicle traveling in the middle lane in the southbound direction on September 22, 2005 at 12:08:03 PM. Information on the 2-axle vehicle as recorded by the WIM system is listed in Table D.5. Figure D.11 shows a 3-axle truck traveling in the middle lane in the southbound direction on September 22, 2005 at 12:08:06 PM. The information on the 3-axle truck as recorded by the WIM system is listed in Table D.6. Figure D.12 shows an image of a 4-axle truck traveling in the middle lane in the southbound direction on September 22, 2005 at 12:20:40 PM. The image also shows a second vehicle of similar type and comparable GVW coming behind the first truck in the same lane. Information on both 4-axle trucks as recorded by the WIM system is listed in Table D.7. Figure D.13 shows an image of a 5-axle truck traveling in the middle lane in the southbound direction on September 22, 2005 at 12:08 PM. Information on the 5-axle trucks as recorded by the WIM system is listed in Table D.8. Figure D.14 shows an image of a 6-axle truck traveling in the middle lane in the southbound direction on September 22, 2005 at 12:17:30 PM. Information on the 6-axle trucks as recorded by the WIM system is listed in Table D.9.

Figure D.10 – 2-axle vehicle traveling in the middle lane in the southbound direction on September 22, 2005 at 12:08:03 PM

Vehicle speed (mph)	# of axles	Total length (ft)	Axle spacing (ft)					Axle weight (kips)						GVW (kips)
			1-2	2-3	3-4	4-5	5-6	1st	2nd	3rd	4th	5th	6th	
33.1	2	18.6	16	--	--	--	--	13.5	34.2	--	--	--	--	**20.7**

Table D.5 – WIM data for the 2-axle vehicle traveling in the middle lane in the southbound direction on September 22, 2005 at 12:08:03 PM

Figure D.11 – 3-axle truck traveling in the middle lane in the southbound direction on September 22, 2005 at 12:08:06 PM

Vehicle speed (mph)	# of axles	Total length (ft)	Axle spacing (ft)					Axle weight (kips)						GVW (kips)
			1-2	2-3	3-4	4-5	5-6	1st	2nd	3rd	4th	5th	6th	
23.4	3	16.5	13.5	3.0	--	--	--	12.2	13.9	13.2	--	--	--	**39.3**

Table D.6 – WIM data for the 3-axle truck traveling in the middle lane in the southbound direction on September 22, 2005 at 12:08:06 PM

Figure D.12 – two 4-axle trucks traveling in the middle lane in the southbound direction on September 22, 2005 at 12:20:40 PM

Vehicle speed (mph)	# of axles	Total length (ft)	Axle spacing (ft)					Axle weight (kips)						GVW (kips)
			1-2	2-3	3-4	4-5	5-6	1st	2nd	3rd	4th	5th	6th	
38.0	4	18.8	14.6	4.5	4.6	--	--	18.9	18.5	19.7	16.9	--	--	**74**
37.6	4	19	14.3	4.3	4.6	--	--	17.7	16.6	25.9	16.6	--	--	**76.8**

Table D.7 – WIM data for the two 4-axle trucks traveling in the middle lane in the southbound direction on September 22, 2005 at 12:20:40 PM

Figure D.13 – 5-axle truck traveling in the middle lane in the southbound direction on September 22, 2005 at 12:08:00 PM

Vehicle speed (mph)	# of axles	Total length (ft)	Axle spacing (ft)					Axle weight (kips)						GVW (kips)
			1-2	2-3	3-4	4-5	5-6	1st	2nd	3rd	4th	5th	6th	
34.5	5	76.3	15.9	4.3	34.8	5.1	--	12.9	20.5	17.4	18.2	17.7	--	**86.7**

Table D.8 – WIM data for the 5-axle truck traveling in the middle lane in the southbound direction on September 22, 2005 at 12:08:00 PM

Figure D.14 – 6-axle truck traveling in the middle lane in the southbound direction on September 22, 2005 at 12:17:30 PM

Vehicle speed (mph)	# of axles	Total length (ft)	Axle spacing (ft)					Axle weight (kips)						GVW (kips)
			1-2	2-3	3-4	4-5	5-6	1st	2nd	3rd	4th	5th	6th	
31.9	6	36.5	15.5	4.4	11.6	4.1	4.4	9.9	23.7	20.2	20.1	25.2	23.7	**122.8**

Table D.9 – WIM data for the 5-axle truck traveling in the middle lane in the southbound direction on September 22, 2005 at 12:17:30 PM

6-axle trucks with configuration similar to the one shown in Figure D.14 and WIM data comparable to what is listed in Table D.9 were not uncommon and are shown in Figure D.15 through Figure D.18. The WIM data recorded for the trucks shown are listed in Table D.10 through Table D.13

Figure D.15 – 6-axle truck traveling in the middle lane in the southbound direction on September 22, 2005 at 12:01:07 PM

Vehicle speed (mph)	# of axles	Total length (ft)	Axle spacing (ft)					Axle weight (kips)						GVW (kips)
			1-2	2-3	3-4	4-5	5-6	1st	2nd	3rd	4th	5th	6th	
40.2	6	40.1	16.7	4.4	15.4	4.3	4.2	10.1	25.2	26.9	27.5	23.6	19.8	**133.1**

Table D.10 – WIM data for a 6-axle truck traveling in the middle lane in the southbound direction on September 22, 2005 at 12:01:07 PM

Figure D.16 – 6-axle truck traveling in the middle lane in the southbound direction on September 22, 2005 at 12:17:30 PM

Vehicle speed (mph)	# of axles	Total length (ft)	Axle spacing (ft)					Axle weight (kips)						GVW (kips)
			1-2	2-3	3-4	4-5	5-6	1st	2nd	3rd	4th	5th	6th	
31.9	6	36.5	15.5	4.4	11.6	4.1	4.4	9.9	23.7	20.2	20.1	25.2	23.7	**122.8**

Table D.11 – WIM data for the 6-axle truck traveling in the middle lane in the southbound direction on September 22, 2005 at 12:17:30 PM

Figure D.17 – 6-axle truck traveling in the middle lane in the southbound direction on September 22, 2005 at 12:40:53 PM

Vehicle speed (mph)	**# of axles**	**Total length (ft)**	**Axle spacing (ft)**					**Axle weight (kips)**						**GVW (kips)**
			1-2	**2-3**	**3-4**	**4-5**	**5-6**	**1st**	**2nd**	**3rd**	**4th**	**5th**	**6th**	
30.1	6	42.5	14.8	4.3	11.5	4.3	4.4	10.3	22.1	19.2	22	19.5	26.6	**119.7**

Table D.12 – WIM data for the 6-axle truck traveling in the middle lane in the southbound direction on September 22, 2005 at 12:40:53 PM

Figure D.18 – 6-axle truck traveling in the middle lane in the southbound direction on September 22, 2005 at 1:17:16 PM

Vehicle speed (mph)	# of axles	Total length (ft)	Axle spacing (ft)					Axle weight (kips)						GVW (kips)
			1-2	2-3	3-4	4-5	5-6	1st	2nd	3rd	4th	5th	6th	
34.1	6	38.7	16.0	4.4	12.2	4.4	4.5	9.1	19.5	20.9	18.5	21.4	18.7	**108.1**

Table D.13 – WIM data for the 6-axle truck traveling in the middle lane in the southbound direction on September 22, 2005 at 1:17:16 PM

D.5.2 WIM, Video, and Stress Time-history Correlation

An example of the correlation made between the WIM data, the video images, and the stress time-history data is shown in Figure D.19. The figure shows the response in strain gages CH_4 and CH_5 installed on the top and bottom flange, respectively, of the east girder in Span 34 and strain gages CH_54 and CH_55 installed on the top and bottom flange, respectively, of the east girder in Span 35 as two trucks crossed side-by-side in the outside and middle lane in the northbound direction. The response in the gages is higher than what was measured during the crawl test CRL2_34. This is expected since the trucks shown in the Figure were heavier than the two test trucks crossing side-by-side in the crawl test. The WIM data associated with the two trucks shown in the Figure is presented in Table D.14. It is important to note that at the beginning of the monitoring period, the data logger, the WIM system, and the cameras were synchronized to a laptop. However, because these pieces equipments do not have internal atomic clocks there was a skew in the time stamps that grew throughout the monitoring period. A review of the data collected on September 22 and between 12:00 PM and 1:00 PM shows a delay of 12-13 seconds between the WIM system and the video recorder with the video lagging the WIM recorder. This explains why the time stamp of the WIM records in Table D.14 is almost similar to the time stamp shown on the video images (the time stamp of the WIM data should be less than that of the video images).

The response of the same gages to the presence of another trucks side-by-side is shown in Figure D.20. The WIM data corresponding to both trucks is listed in Table D.15. As shown in Figure D.20, the response of the gages to the crossing of the trucks is less than that of Figure D.19. Furthermore, dynamic vibration of the girders is shown to be higher in Figure D.20 than what is shown in Figure D.19. Figure D.21 is another example of two side-by-side trucks passing over Span 34 in the outside and middle lane and the corresponding response in strain gages CH_4, CH_5, CH_54, and CH_55. Table D.16 lists the WIM data corresponding to the passage of the two trucks.

It is important to point out that error was observed in some of the collected WIM data. The error was due to the fact that some of the vehicle's axles were not detected by the loop sensors, resulting in a total GVW lower than the actual weight of the passing vehicle. The instability in the performance of the sensors became more evident towards the end of the monitoring period as the sensors were starting to wear out. As shown in Figure D.21, the response of strain gage CH_5 to the crossing of a 6 axle truck in the middle lane and what appears to be also a 6-axle truck in the outside lane was approximately 3 ksi. The WIM data however (Table D.17), shows each truck had total number of axles of 3, and therefore the resulting GVW of the trucks is lower than the actual weight.

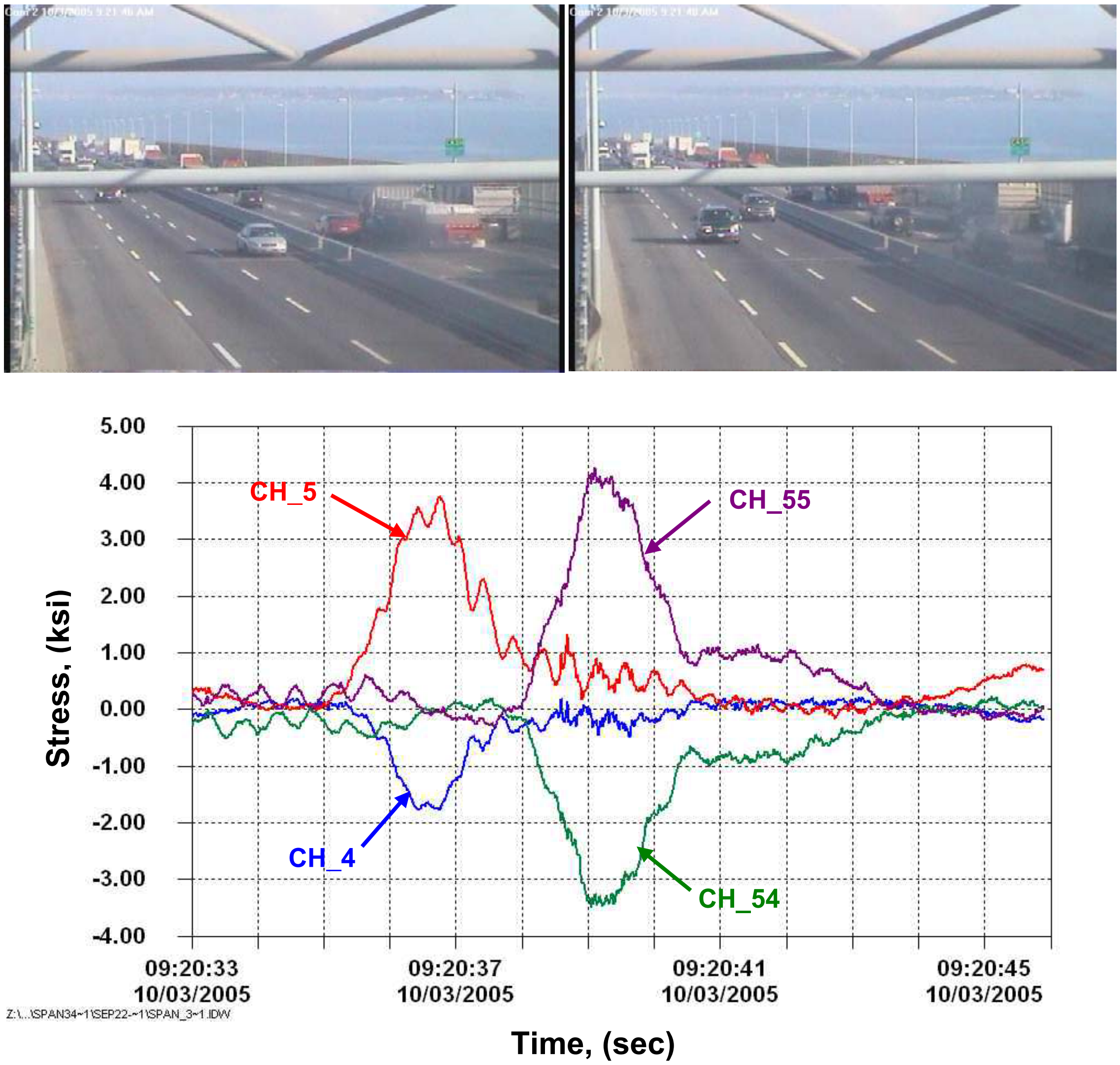

Figure D.19 – Images of 6 and 5-axle trucks traveling in the outside and middle lane, respectively, in the northbound direction on October 3, 2005 at 9:21:46 AM and the corresponding response of the gages installed on the top and bottom flange of the east girder in Span 34 and Span 35

Time stamp	Lane #	Vehicle speed (mph)	# of axles	Total length (ft)	Axle weight (kips)						GVW (kips)
					1st	2nd	3rd	4th	5th	6th	
9:20:47	1	46	6	42.8	11.4	25.1	21.5	19.8	24.4	23.2	**125.4**
9:20:51	2	49.6	5	41.5	8.7	13.3	14.7	11.7	10.1	--	**58.5**

Table D.14 – WIM data for the 6 and 5-axle trucks traveling in the outside and middle lanes in the northbound direction on October 3, 2005 at 9:21:46 AM

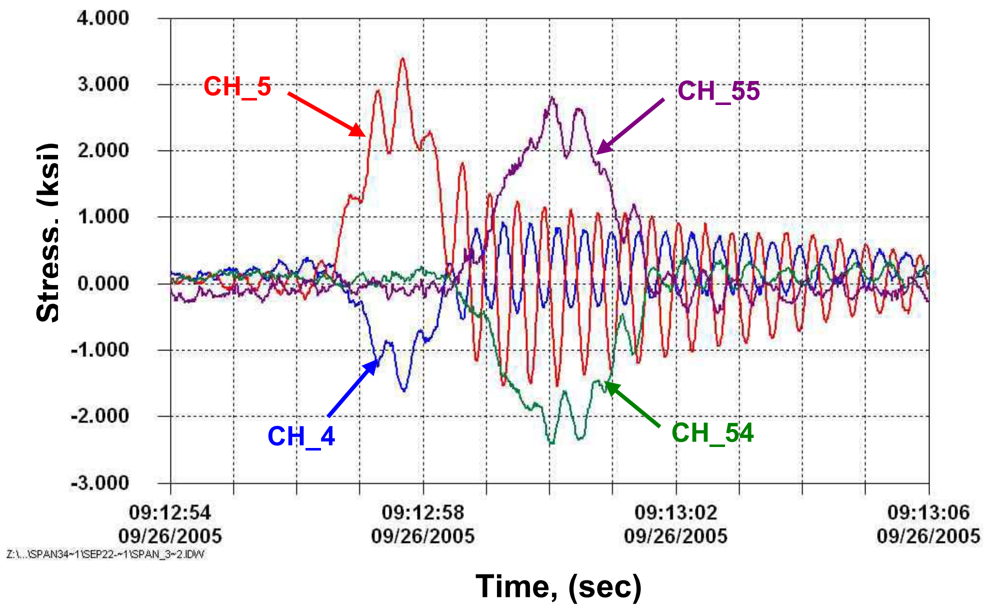

Figure D.20 – Images of 4 and 5-axle trucks traveling in the outside and middle lane, respectively, in the northbound direction on September 26, 2005 at 9:13 AM and the corresponding response of the gages installed on the top and bottom flange of the east girder in Span 34 and Span 35

Time stamp	Lane #	Vehicle speed (mph)	# of axles	Total length (ft)	Axle weight (kips)						GVW (kips)
					1st	2nd	3rd	4th	5th	6th	
9:13:00	1	48.0	4	21.8	18.7	8.2	27.4	22.9	--	--	**77.2**
9:13:01	2	64.5	5	66.3	14.3	22	24	21.6	22.6	--	**104.5**

Table D.15 – WIM data for the 4 and 5-axle trucks traveling in the outside and middle lanes in the northbound direction on September 26, 2005 at 9:13 AM

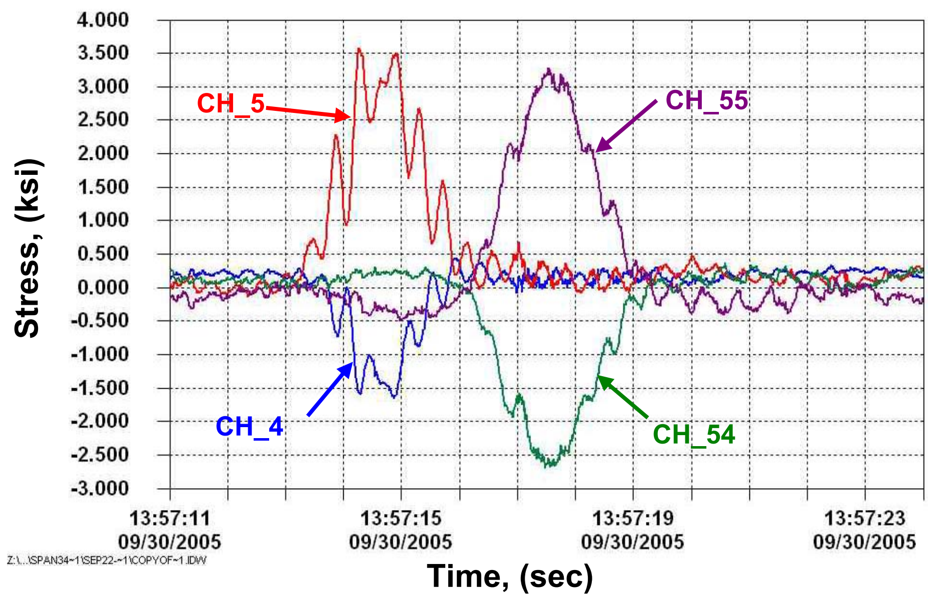

Figure D.21 – Images of 6 and 5-axle trucks traveling in the outside and middle lane, respectively, in the northbound direction on September 30, 2005 at 1:57:22 PM and the corresponding response of the gages installed on the top and bottom flange of the east girder in Span 34 and Span 35

Time stamp	Lane #	Vehicle speed (mph)	# of axles	Total length (ft)	Axle weight (kips)						GVW (kips)
					1st	2nd	3rd	4th	5th	6th	
13:57:22	1	32.4	6	28	7.9	19.4	16.3	17.4	23.1	22.2	**106.3**
13:57:22	2	50.4	5	39.5	8.7	11	10.7	11.7	9.6	--	**51.7**

Table D.16 – WIM data for the 6 and 5-axle trucks traveling in the outside and middle lanes in the northbound direction on September 30, 2005 at 1:57:22 PM

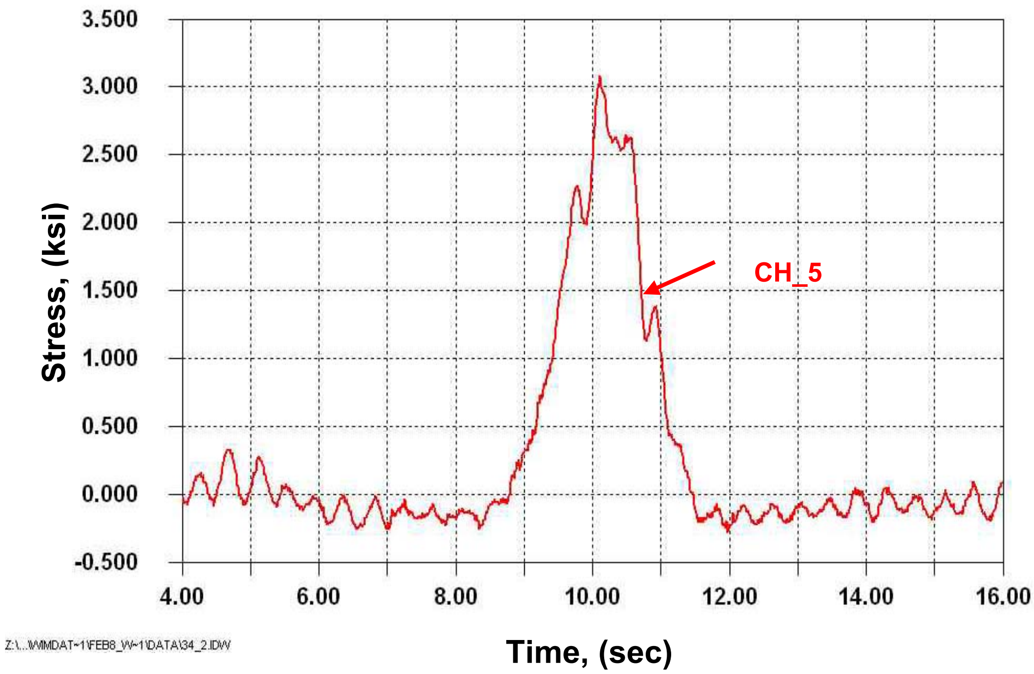

Figure D.22 – Images of 6-axle trucks traveling side-by-side in the outside and middle lane, respectively, in the northbound direction on September 23, 2005 at 5:27:01 AM and the corresponding response of strain gage CH_5 installed on the bottom flange of the east girder in Span 34

Time stamp	Lane #	Vehicle speed (mph)	# of axles	Total length (ft)	Axle weight (kips)						GVW (kips)
					1st	2nd	3rd	4th	5th	6th	
5:27:01	1	56.0	3	17.2	10.7	31	23.2	19.9	28.3	21.9	**135**
5:27:01	2	54.3	3	24.2	10.9	18.7	17.8	--	--	--	**47.4**

Table D.17 – WIM data for the 3-axle trucks traveling in the outside and middle lanes in the northbound direction on September 23, 2005 at 5:27:01 AM

D.5.3 Approximation of Maximum Truck Weight by Correlating WIM, Video, Stress Time-history, and Controlled Load Tests

The unreliable performance of the WIM sensors, in some cases, made it impossible to characterize the vehicle weight distribution during the one week monitoring period. To approximate the maximum weight of trucks passing over the bridge during the WIM monitoring period of one week, it was decided to investigate the WIM data, the video images, the stress-time history obtained during the one week of WIM study, and results of the dynamic controlled load tests.

A review of the time-history response of strain gage CH_5 during the one week of WIM data collection showed a total of 19 events in which the peak response in strain gage CH_5 exceeded 3 ksi. The video images corresponding to all of the 19 events show that a peak response of 3 ksi or higher was caused by multiple presence of trucks/vehicles on the bridge, primarily in the outside and middle lane. In all events, vehicles or trucks were present in the inside lane along with the in the outside or middle lane.

During the one-week monitoring period, it was found that thousands of events were recorded where the peak stress value in strain gage CH_5 was below 3 ksi. One could assume that an event with a peak stress of 2.9 ksi could have been caused by a single truck passing in the outside, middle, or inside lane. As shown in Table 5.85, the peak response of strain gage CH_5 installed on the bottom flange of the east girder in Span 34 as Truck #1 weighting approximately 84 kips and traveling in the outside lane was approximately 1.5 ksi. Therefore, a peak event of 2.9 ksi could be produced by a single truck weighting approximately 160 kips passing in the outside lane. Similarly, Truck #3 (~ 80 kips) traveling in the middle lane produced a peak stress value of 1 ksi in strain gage CH_5 during the dynamic controlled test (DYN2_34). Therefore, a single truck weighing approximately 230 kips traveling in the middle lane will result in a peak response of approximately 2.9 ksi in strain gage CH_5. Finally, Truck #5 (~ 81 kips) traveling in the inside lane produced a peak stress value of 0.8 ksi in strain gage CH_5 during the dynamic controlled test (DYN2_34). Therefore, a single truck weighing approximately 290 kips traveling in the middle lane will result in a peak response of approximately 2.9 ksi in strain gage CH_5.

As mentioned above, thousands of events were recorded during the one-week monitoring where the peak stress value in strain gage CH_5 was below 3 ksi. A random review of many video images collected during the monitoring period showed no events of a single truck passing in the middle or outside lane. Such observation, with possible exceptions, leads to the conclusion that **none of the trucks on the bridge weighed above 160 kips during the one week of WIM monitoring**

It is worth noting that a 7-axle truck crossed over the bridge on September 26, 2005 at 2:57 AM and weighted approximately 220 kips according the TBTA records. The truck caused a peak stress value of 4.9 ksi in strain gage CH_5 and crossed the over Span 34 (191 ft) in approximately 10 seconds (i.e. the truck was traveling over the span in speed of approximately 13 mph.) As expected, the WIM data corresponding to this event was unreseaonable since the truck was traveling in speed less than what is needed for accuracy (20 mph as recommended by IRD).

It is important to note that the stress-range histograms developed during the week of WIM monitoring shows that approximately 100 events were recorded for an average stress range of approximately 3.25 ksi. This is an average stress range, not the peak magnitude of stress as noted above. As shown in Figure D.23 the girder vibrated as it responded to the moving of the trucks resulting in a negative response in strain gage CH_5 installed on the bottom flange and a total stress range of about 3.5 ksi. Figure D.24 shows the response of strain gage CH_5 during the controlled load test DYN2_34. The six peaks shown in the figure represent the passage of Truck 1 in the right lane (first peak), followed by Truck 2 in the same lane (second peak), followed by Truck 3 in the middle lane (third peak), followed by Truck 4 also in the middle lane (fourth peak), followed by Truck 5 in the left lane (fifth peak), and finally Truck 6 also in the left lane (sixth peak). The vibration of the east girder resulted in a compressive stress in the range of 0 – 0.25 ksi with the exception of the response of the passage of the second truck, which resulted in a compressive stress of approximately 0.6 ksi. In some cases during the random monitoring however, the magnitude of the compressive stress resulting from the vibration of the girder was on the order of 1.5 ksi as shown in Figure D.20. Such a high magnitude of compressive stress resulting from excessive vibration, which was not captured during the dynamic controlled load test, resulted in an increase in the total stress range experienced by the strain gage. Therefore, only the peak stress value of the response of the strain gage was used for correlating the random time history response with the dynamic controlled load test as explained above.

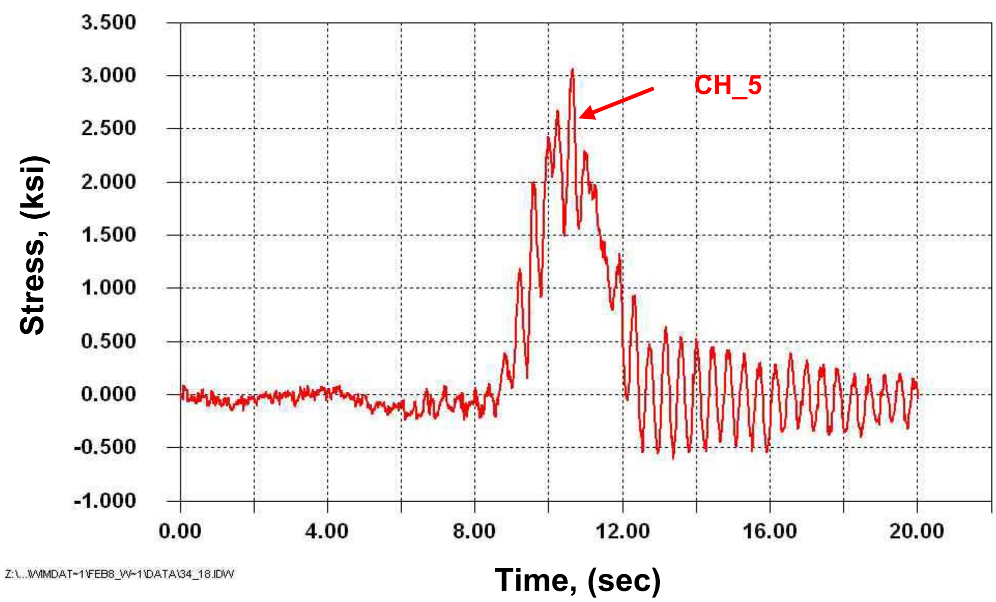

Figure D.23 – Images of 6 and 5-axle trucks traveling in the outside and middle lane, respectively, in the northbound direction on October 1, 2005 at 10:55:08 AM and the corresponding response of strain gage CH_5 installed on the bottom flange of the east girder in Span 34

Time stamp	Lane #	Vehicle speed (mph)	# of axles	Total length (ft)	Axle weight (kips)						GVW (kips)
					1st	2nd	3rd	4th	5th	6th	
10:54:15	1	43.4	6	15.4	10.7	31	23.2	19.9	28.3	21.9	**135**
10:54:17	2	44.3	3	16.6	10.9	18.7	17.8	--	--	--	**47.4**

Table D.17 – WIM data for the 6 and 3-axle trucks traveling in the outside and middle lanes in the northbound direction on October 1, 2005 at 10:54:17 AM

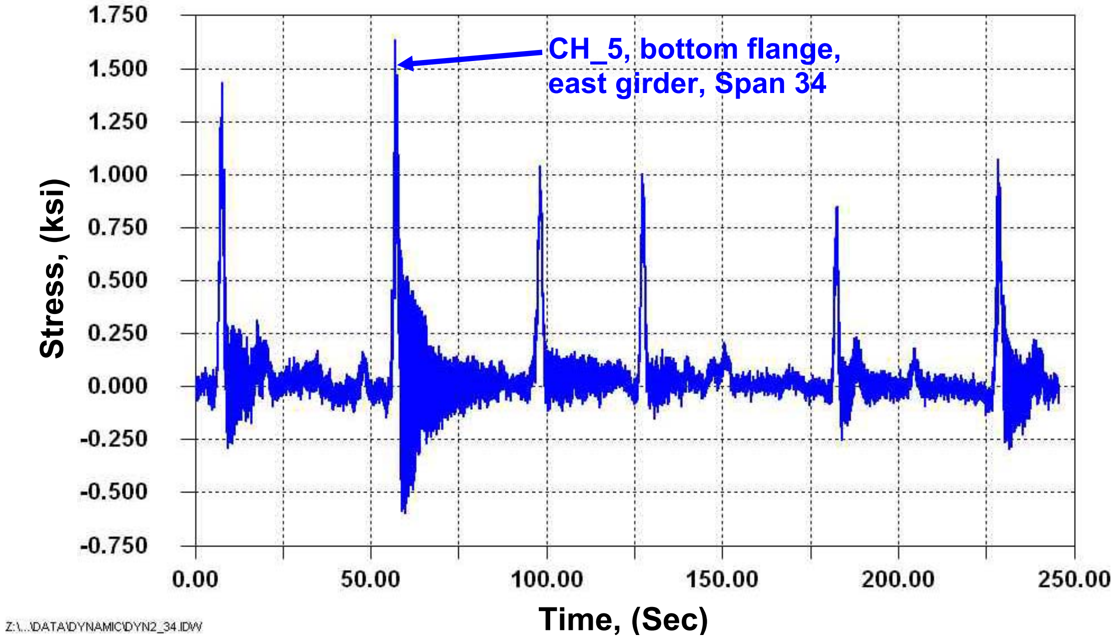

Figure D.24 – Response of strain gage CH_5 installed on the bottom flange of the east girder in Span 34, approximately 4 in north of midspan as the test trucks crossed in the northbound direction over all three lanes in the dynamic test DYN2_34